AM
1948
Gar
c.1

Boston University

College of Liberal Arts
Library

BOSTON UNIVERSITY

GRADUATE SCHOOL

Thesis

THE WEIGHT OF BIRDS IN RELATION TO THEIR LIFE CYCLES

by

William Vaughn Garner

(B.S., Ursinus College, 1947)

submitted in partial fulfilment of the

requirements for the degree of

Master of Arts

1948

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

AM
1948
har
c.1

Approved

by

First Reader. Stuart K. Harris.....

Professor of Biology

Second Reader. Ralph B. Ruddy.....

~~Professor of~~
Instructor in Biology

Contents:

I.Introduction.	Page 5
2.The History of Bird Weight Taking.	Page 7
3.The Methods Used to Take Bird Weights.	Page 9
4.A General Survey of Average Bird Weights.	Page I2
5.Weight Variation With Age.	Page 50
6.Weight Variation With Sex.	Page 64
7.Weight Variation With the Time of Day.	Page 70
8.Weight Variation With the Amount of Food Consumed.	Page 76
9.Weight Variation With Temperature.	Page 80
IO.Weight Variation With Time of Year, Migration,and Molt.	Page 86.
II.Weight Variation With Disease and Parasitism.	Page 94
I2.Weight Variation During the Breeding Season.	Page 97
I3.Weight Variation With Locality and Subspecies.	Page I02
I4.Weight Variation Due to Miscellaneous Factors.	Page I07
I5.Conclusions.	Page II0
I6.Thesis Abstract.	Page II4
I7.Bibliography.	Page II8

Illustrations:

I. Table showing the decrease of egg weight with time, and the different weights of eggs from the same set of the sora rail, Porzana carolina. Page 51

2. The growth curve of a nestling eastern nighthawk, Chordeiles minor. Page 55

3. The growth curve of two nestling black-throated green warblers, Dendroica virens. Page 56

4. The growth curve of a nestling eastern cowbird, Molothrus ater ater. Page 57

5. Table showing the gain and loss in weight of a nestling eastern chipping sparrow, Spizella passerina passerina. Page 59

6. Graph showing the sexual differentiation in weight of twenty five male and twenty five female nestling red-winged blackbirds, Agelaius phoeniceus. Page 65

7. Chart showing the hourly weight rhythm of one hundred and sixty five goldfinches, Spinus tristis tristis. Page 71

8. Graph showing the weight variation of the song sparrow, Melospiza melodia, during a twenty four hour period. Page 74

9. Chart of many species showing the inverse relation between size and relative food consumption. Page 76

10. Table showing the variability in weight of adult chipping sparrows, Spizella passerina passerina, correlated with the number of times captured and weighed. Page 78

11. Graph showing the relation of temperature to the rate of growth in nestling barn swallows, Hirundo rustica erythrogaster. Page 80

12. Two charts illustrating the correlation between body weight and air temperature, the first in an adult male song sparrow, Melospiza melodia, the second in an adult male tree sparrow, Spizella arborea. Page 83

13. Graph of five species showing the monthly weight variation throughout the year. Page 87

14. The weight variation of a white-throated sparrow, Zonotrichia albicollis, during a stop-over period of three days during migration. Page 91

I5. Chart showing the loss in weight of dead tree sparrows, Spizella arborea. Page 96

I6. Graph showing the weight curves of both male and female yellow-eyed penguins, Megadyptes antipodes, during the pre-egg, post-egg, and guard periods. Page 98

I7. Chart showing the comparative weights of chicks and chick brains of the wild turkey, Melegagris gallopavo, and the domestic and hybrid strains. Page I04

I8. Table showing the comparative weights of the males and females of twelve subspecies of the horned lark, Otocoris alpestris. Page I05

I9. Table showing the relation of fat to body weight in the Oregon junco, Junco oreganus. Page I09

Introduction:

There is a striking dearth in American ornithological literature of data on the body weights of even our most common song birds, probably due to lack of a suitable weighing instrument. A more important reason may lie in the recognized variability of bird weights, and consequent lack of appreciation of their importance, yet there are many biological problems on which the weight of birds, and the variation and fluctuations of these weights, will throw a light. A concrete example will illustrate what is meant. On February 18, 1926, two exceptionally large song sparrows were taken from a trap in Peterboro, N.Y., to be weighed by Myers (1928). The birds escaped however and were killed by flying against a window. Since the birds were not only longer than the Eastern song sparrow, Melospiza melodia melodia, but appeared much heavier, it was decided to weigh and dissect the recently dead specimens. The female was found to weigh 26.0 grams and the male 26.5 grams, about 4 grams heavier than the average weight of the common Eastern song sparrow. Dissection revealed little fat and no enlargment of the sex organs. The crops of both were about one-fourth full, and no difference in plumage from that of the common song sparrow was observed. Large song sparrows such as these two birds had been noticed for some years, but none had ever before been weighed, and while the above data are not conclusive, it strongly suggests there is perhaps a larger

more robust race of Eastern song sparrow,found during the breeding season only at the northern limit of the common bird's range.This biological problem could undoubtedly be settled,one way or the other,by more weighings and study of these larger song sparrows by both professional and amateur ornithologists alike.

The purpose of this paper then,is to correlate as much material as possible on the subject of bird weight,in an effort to show its importance,not only in the life cycles of birds,but also as a possible clue to some of the many perplexing problems still existing in ornithology.

The method used in attacking this problem was to review the literature on the subject,as found in several leading ornithological publications.The data,once collected,was then studied,analysed,and correlated in an effort to present the facts in a logical yet concise manner.This paper must by no means be regarded as the final word on the subject,for in this relatively new branch of ornithology the surface has been merely scratched,with much work remaining to be done.

The History of Bird Weight Taking:

It is extremely difficult to give the exact date when bird students first began to record weights and attempted to interpret the results as an integral part of certain biological phenomena in the lives of birds.Even as recently as I926,the ornithologist Andrews(1926) said,"..the weight of the song bird is not a feature recorded by the ornithologist to any extent.To find the weight of a Cardinal Bird we must either shoot one or look for information in unusual publications..".

Even the European ornithologists,usually well advanced in many aspects of biological research,had failed to explore this virgin field,with the exception of a few well isolated examples.According to Esten(I93I) the first American to record weights with any regularity was William B.Van Gorder, who lived in Indiana from I855 to I927.This gentleman not only studied the habits of birds,but kept migration notes and banded them for over forty years,and in I9II began to record the weights of the birds he banded.Although his notes over this long span of years covered only fifty two species,he also recorded the date,the condition of the birds,and the sex if known,which was at least a step in the right direction.

Within approximately the last twenty years however,as the study of bird migration became more intensified by means of the live trap and the aluminum band,weights began to be taken

as a natural part of this study.Gradually data was accumulated through the efforts of many banders from all over the country, and articles on the subject began to appear in various leading ornithological journals such as The Auk,The Condor,Wilson Bulletin,and Bird Banding.Variations in weight were noted in these articles,but at the same time it was also realized that these variations and fluctuations in weight were not due alone to the recent feeding of the birds,as was originally believed, but that other important factors entered into the picture.

Today many of our leading ornithologists,both professional and amateur,are working on the problem of bird weight from many standpoints,and this branch of science is finally coming into its own."Workers such as D.Amadon,S.C.Kendeigh,S.P.Baldwin, M.M.Nice,and others have done admirable work in this field,not only through their direct weighings,but also by their interpretation of the data.It should be emphasized that weights should be taken whenever possible,even of dead specimens,for with thousands of bird students all over the country,the opportunity for recording and study is unlimited,and the more data accumulated the clearer will the interpretation of this problem become.

The Methods Used to Take Bird Weights:

As stated earlier, one of the main reasons for the almost total lack of data on the subject, prior to about twenty years ago, was the difficulty encountered in weighing the specimens. Dead birds could be weighed with ease, but when it came to living birds many problems arose, such as the use of an accurate enough balance, and the handling of the bird without injury. Today, at small cost and with inexpensive equipment, the process is simple, quick, and accurate, but years ago many methods were tried and found to be generally unsatisfactory. For example Samuel Prentiss Baldwin (1924) once got the idea that house wrens, Troglodytes aëdon, could be weighed as they came to their box-nest by stepping on a specially prepared perch, which made an electrical contact and thus recorded their weight. This unique device, originally called the 'wrenograph', was not satisfactory to any great extent because it was too complicated, and could be used only in the vicinity of the nest. It was later modified however, the name changed to 'itograph', and since then has not only been successfully applied to several species with open nests not in boxes, but has also been used to record the activity of certain mammals and reptiles.

Various other pioneers in the field tried to place the birds in specially constructed boxes, both wood and metal, but they proved impractical as well as time consuming. Many types of balances were tried also, but proved either too delicate or

too difficult to manipulate in the field.

After many years of trial and error the process was finally reduced to one of relative simplicity,and is now used almost universally throughout the country by bird weighers. The scale used is the Chatillon dietetic spring balance,which is not only inexpensive,but also simple in construction and operation.This balance has the advantage of a movable dial, graduated in grams and fractions thereof,by means of which the tare-weight of the bird container may be neutralized,and the weight of the bird read directly off the dial without any subtraction.No time consuming manipulation of weights is required,and accuracy is within one-half a gram,often less. The bird to be weighed is placed in a sack of soft Canton flannel of various sizes,depending on the species involved.For the majority of birds one of I2 inches in length with an opening of 6 inches in diameter is sufficient.The bird is quickly inserted into the sack and held in the closed end by the free hand on the outside.The free end of the sack is then wrapped snugly about the bird so that the wings are pinned against the sides in a natural position.No drawstring is needed,as the bird remains perfectly motionless while being weighed if properly placed in the sack.Injury to the bird by this procedure is unlikely if done correctly,and the chance of smothering is practically impossible since the entire process requires not more than about twenty or thirty seconds.

Many bird weighers find that in order to record all possible data, each bird is given its own index card of information. On this card is recorded the age and sex of the bird, if known, the date and hour of the weighing, the approximate amount of ingested food as influenced by availability prior to weighing, individual distinguishing characteristics, such as band number, to aid in recognizing the bird if captured again, and the recorded weight.

This procedure, taken from Myers(1928), Stewart(1937), and Baldwin and Kendeigh(1938), can be done with a minimum of both trouble and expense, and if practiced more extensively, would be a great aid in clarifying the problem of weight variation and fluctuation in birds.

A General Survey of Average Bird Weights:

To attempt to list taxonomically the average body weights of our North American birds would be impossible for several reasons. In the first place there is no such thing as a 'true' average weight for any given species, for body weight varies with sex, age, season, temperature, time of day, and other factors. Secondly the weights of many species of birds are not known, and many have only a few scattered records. Therefore the body weights of birds will be discussed generally under four headings; Water and Shore Birds, Birds of Prey, Non-passerine Land Birds, and Passerines. This section, which will not go into the problem of weight variation, is simply to break the birds up into various weight groups as a means of comparing one large grouping with another, as far as information is available. It is also hoped that it will show how certain basic information in some of these groups is lacking with regards to the problem of weight. Since the weight of immatures will be taken up later, only adult birds will be considered at this time.

A.Water and Shore Birds:

Under this grouping fall eight orders.-Gaviiformes:Loons, Colymbiformes;Grebes,Procellariformes:Tube-nosed swimmers, including shearwaters,petrels,and albatrosses,Pelecaniformes: Totipalmate swimmers,or pelicans,cormorants,and gannets, Ciconiiformes:Herons and their allies,Anseriformes:Ducks, geese,and swans,Gruiformes:Cranes,rails and allies,and Charadriiformes:Shore birds,gulls,and allies.

This large group of birds,on the whole,unfortunately lacks much information as to the body weights of adult individuals. A few species have been investigated to a fair extent,but the weights of too many species are scanty,even lacking in some cases.For example Musselman(I936)weighed two adult avocets, Recurvirostra americana,which were shot during the fall on the Mississippi River in Illinois,and found both to weigh around 3I2 grams.Since these birds were undoubtedly migrating, when weight varies a great deal,and since no weights for avocets on their breeding grounds are available,these figures are of little value until more work is done on this species.

The literature is full of isolated facts such as the above example,even of relatively common birds.For example only three weights could be found for the common loon,Gavia immer. Van Gorder(I93I)weighed a male and a female in March,and found the weights to be 3,629 grams and 3,260 grams respectively.On the other hand,Poole(I938)found a female loon

to weigh only 2,425 grams.Since the age and condition of the latter individual was not stated,it can hardly be possible that adult female loons normally vary as much as 835 grams, and when more information is available on this species it will probably be found to be false.

Comparisons can be made in certain groups of the 'Water and Shore Birds' such as the ducks,which have been studied more intensively.Just as the weights of no two individual birds of any given species are exactly the same at all times, so it is with certain species of approximately the same length and size.This is brought out by comparing the weights of adult baldpates,Mareca americana,with those of adult gadwalls, Anas strepera,as taken from Bellrose and Hawkins(1947).

	Length	Number weighed	Average weight
Baldpate	18-21 in.	19	361.7 grams
Gadwall	18-21 in.	16	430.7 grams

These two species of ducks are of practically the same length,yet their average weights differ to the amount of almost 70 grams.Other species such as the wood duck,Aix sponsa,and the shoveller,Spatula clypeata, both from 17-20 inches in length,vary very slightly in weight when compared, ten adult male wood ducks averaging 301.8 grams,and nineteen adult male shovellers averaging 300.3 grams. Adult male

canvasbacks, Aythya valisineria, average as high as 588.8 grams at one extreme in the ducks, and adult male green-winged teals, Anas carolinensis, as low as I70 grams at the other extreme. Kortright(I943) lists the Canada goose, Branta canadensis, as averaging between 3000-3500 grams, the whistling swan, Cygnus columbianus, between 5300-5800 grams, the mallard, Anas platyrhynchos, between 950-I000 grams, the black duck, Anas rubripes, between 950-I000 grams, and the American merganser, Mergus merganser americanus, as between I400-I500 grams, among others.

The Alcidae, which includes the auks, murres, and puffins, vary greatly in average body weight for no apparent reason. Gross(I937) found a great discrepancy in weight among healthy adult birds of the same age. For example the puffin, Fratercula arctica, was found to vary in weight from II4 to 485 grams, a difference of 37I grams. The black guillemot, Cepphus grylle, ranged from I05.8 grams up to 450 grams, a difference of over 345 grams, and the dovekie, Plautus alle, from I46 to I90 grams, a difference of 44 grams. Johnson(I935) even took an adult male dovekie in Nova Scotia weighing only I27 grams, which upon dissection was found to possess a considerable layer of sub-cutaneous fat.

Gross(I937) lists the least sandpiper, Erolia minutilla, as averaging about 22 grams, the purple sandpiper, Erolia maritima, as between 60-70 grams, the white-rumped sandpiper, Erolia fuscicollis, between 50-55 grams, and the semipalmated

sandpiper, Ereunetes pusillus, between 20-22 grams.

Perhaps the main reason why the 'Water and Shore Birds' have not been weighed more than they have is the difficulty involved in trapping them. Since the great majority are pelagic, roaming over great stretches of water for the most part, the only places to really weigh and study them are on their breeding grounds, such as remote ocean islands, the interior of northern Canada, the Florida Keys, and other spots inaccessible to the average bird weigher. Little is known about the group as a whole with regard to weight, and since there are over two hundred species in all in North America, they will undoubtedly furnish much interesting data once more study on them is made.

B. Birds of Prey:

Two orders comprise this group, the Falconiformes, including the diurnal vultures, hawks, falcons, and eagles; and the nocturnal Strigiformes, or owls. The following chart was compiled from Esten(1931), Stewart(1937), Poole(1938), Nice(1938), and Baldwin and Kendeigh(1938). In all cases sufficient records were available to comprise a general average.

Falconiformes:

Species.	Average weight range.
Turkey Vulture Cathartes aura	2400-2550 grams
Eastern Goshawk Accipiter gentilis atricapillus	800-900 grams
Mexican Goshawk Asturina plagiata	400-500 grams
Sharp-shinned Hawk Accipiter striatus velox	90-175 grams
Cooper's Hawk Accipiter cooperii	420-600 grams
Red-tailed Hawk Buteo jamaicensis	875-1300 grams

Red-shouldered Hawk Buteo lineatus	750-850 grams
Broad winged Hawk Buteo platypterus	350-400 grams
American Rough-legged Hawk Buteo lagopus	900-I050 grams
Bald Eagle Haliaeetus leucocephalus	4500-5000 grams
Golden Eagle Aquila chrysaetos canadensis	4500-5500 grams
Marsh Hawk Circus cyaneus hudsonius	400-600 grams
Osprey Pandion haliaëtus carolinensis	I800-2I00 grams
Duck Hawk Falco peregrinus anatum	750-I250 grams
Pigeon Hawk Falco columbarius	I70-220 grams
Sparrow Hawk Falco sparverius	II0-I40 grams

Strigiformes:

Barn Owl Tyto alba pratincola	450-525 grams
Screech Owl Otus asio	I50-600 grams

Great Horned Owl *Bubo virginianus*	I450-I550 grams
Barred Owl *Strix varia*	500-600 grams
Long-eared Owl *Asio otus wilsonianus*	225-300 grams
Short-eared Owl *Asio flammeus*	300-400 grams
Saw-whet Owl *Aegolius acadica*	85-II5 grams

By examining this chart it will be noted that certain species vary very little in average body weight, while others such as the screech owl, red-tailed hawk, and duck hawk have a rather wide weight range. Since all but the vultures are predatory, depending on both skill and abundance of prey for their sustenance, perhaps the regularity and amount of recent feedings may enter into the picture much more so than in other groups of birds. For example two screech owls weighing I22.6 and II4 grams respestively were noted by Hartman(I946) to be in a starved condition, a situation which could be eliminated by greater food supply. Apparently raptorial birds which feed fairly regularly maintain a rather constant body weight. Just how long they can maintain this average weight without becoming starved is not known, but certainly offers opportunity

for some interesting experiments on the subject.Although this list does not include all of the raptorial birds to be found in North America,it does give a general idea of the weight range in the majority of the species,from the eagles at one extreme to the sparrow hawk and saw-whet owl at the other extreme.

C.Land Birds other than Passerines:

This grouping includes the Columbiformes:Pigeons and doves,Cuculiformes:Cuckoos and anis,Caprimulgiformes: Whip-poor-wills and nighthawks,Micropodiformes:Swifts and hummingbirds,Coraciiformes:Kingfishers,Piciformes: woodpeckers,and Galliformes:Fowl-like birds.Since there are over one hundred representatives in the United States alone, the group will be discussed by orders rather than by species.

I.Columbiformes:

Although this order comprises some twelve species,only two have been weighed in sufficient numbers to arrive at an average body weight.The domestic pigeon,Columba livia,which is feral in many places,roughly averages between 300-325 grams. The literature,however,does not state whether or not the birds weighed were semi-wild or domesticated,so the figures are of little value,since pigeons kept by man under somewhat uniform conditions would have a tendency to be heavier than birds which have to forage for their food.Reliable comparative figures are available,however,for the mourning dove,Zenaidura macroura,the commonest member of this order in North America. In this bird some eighty adult weights are available from Poole(1938) and Nice(1938),with the average body weight being between 132 and 138 grams.If the mourning dove may be taken as an indication,the Columbiformes vary very little in general body weight,but this theory cannot be accepted until

figures are available on other members of the order such as the ground dove,Columbigallina passerina,the white-crowned pigeon,Columba leucocephala,the band-tailed pigeon,Columba fasciata,and the others.

2.Cuculiformes:

Only two weights are available on the yellow-billed cuckoo,Coccyzus americanus,61 and 57.8 grams respectively, both taken from Poole(1938).More figures are available on the smooth-billed ani,Crotophaga ani,a semi-tropical bird occasionally found as far north as Louisiana and southern Florida.Both the cuckoos and anis are about twelve inches in length,but the smooth-billed ani has very short wings and hence is a poor flyer.Davis(1940) not only weighed numerous individuals of this species,but also calculated the weight of the feathers.He found the adults to average between 97 and 115 grams,the males being slightly heavier.At the time of egg-laying,however,he found the females to increase in weight due to eggs and excess fat,and to equal the males in weight for this comparatively brief period of time.The weight of the feathers was calculated by obtaining the difference between the weight of the bird before and after stripping it of all its feathers except the remiges and retrices,and was found to roughly equal three per cent of the total body weight.Since these birds are mainly semi-tropical,it would be interesting to work out what per cent of total weight feathers make up in temperate and northern birds,which must face much more

rigorous climatic conditions and would be thought to have a heavier coating of feathers than do tropical birds.

3.Caprimulgiformes:

This order includes the nighthawks and the whip-poor-wills. No figures are available on the whip-poor-wills and only a very few on the nighthawk.In the latter bird,Chordeiles minor, the weight of three adults ranged from a low of 60 grams to a high of 105 grams.If these birds were all of the same sex and weighed under the same conditions this would be a wide variation indeed,but since Fowle(1946) does not state,these figures are probably not too reliable.

4.Micropodiformes:

This order includes the swifts and hummingbirds.The hummingbirds are the smallest birds in both size and weight, in fact weigh so little,their weights are normally recorded in grains,but are here converted to grams for easier comparisons.According to Esten(1931),the ruby-throated hummingbird,Archilochus colubris,weighs from 2.5 to 3.5 grams, and the black-chinned hummingbird,Archilochus alexandri,from 2.0 to 2.8 grams.The other sixteen species of hummingbirds, found west of the Mississippi River,have no recorded weights. Of the swifts,only the common chimney swift,Chaetura pelagica, has been weighed in sufficient numbers to warrant arriving at a good general average body weight.Stewart(1937) weighed forty-seven adults and found them to range from 21 to 27

grams,with a mean of 24 grams.Other figures in the literature corroborate his work.

5.Coraciiformes:

There are only two species of kingfishers found in the United States,the common belted kingfisher,Megaceryle alcyon, between eleven and fourteen inches in length,and the much smaller Texas kingfisher,Chloroceryle americana septentrionalis,which is a little over seven inches in length. It is interesting to note in the case of the kingfishers that while the belted kingfisher is about twice the length of the Texas kingfisher it weighs four times as much,the former bird averaging between I35 and I65 grams,and the latter from only 30 to 40 grams,as taken from Davis(I944).

6.Piciformes:

While there are over twenty five species of woodpeckers to be found in North America,only a comparatively few have been weighed in sufficient numbers to make a worthy comparison.The downy woodpecker,Dendrocapus pubescens,has probably been weighed more often by more weighers and banders than any other woodpecker,and all come to practically the same result.For example Stewart(I937) weighed sixteen adults and found them to average 26.7 grams,with a high of 29.5 grams and a low of 23.7 grams.Hartman(I946) weighed thirty adults and found them to vary plus or minus two grams around a mean average of 26.9 grams,a very comparable figure.Other

weight records in the literature on this species agree with the above figures.Average body weights of other woodpeckers taken from the same two sources are as follows:

Species	Number weighed	Weight range
Flicker Colaptes auratus	20	I20-I40 grams
Hairy woodpecker Dendrocopus villosus	I0	65-75 grams
Yellow-bellied sapsucker Sphyrapicus varius	9	40-50 grams

As for the some twenty one other species of woodpeckers to be found in North America,either no adult weights are available,or too few birds have been weighed to accept them as average weights for the species in question.

7.Galliformes:

While this order contains only twenty four species to be found in the United States,many figures are available mainly through the efforts and work done by the Fish and Wildlife Service and various other agencies interested in game birds. Although there are many figures,for example,on the weights of the bob-white,Colinus virginianus,and the ring-necked pheasant,Phasianus colchicus torquatus,caution should be made to compare only the weights of known wild birds,since birds raised on game-farms tend to be a good deal lighter.

Why this interesting fact should be is not known, for it would seem that birds fed regularly and raised under uniform conditions would be heavier than birds which have to forage for their food under many diverse environmental conditions. Perhaps the factors of instability and nervousness enter into the picture a good deal, for these birds are very difficult to raise. For example I have seen ring-necked pheasants raised from the egg in Pennsylvania that were small, nervous, and very shy, yet they were given more than enough to eat. Errington(1936) found that eighty one adult wild pheasants averaged between 950 and 1250 grams, several hundred grams heavier than birds raised on game-farms. Stoddard(1931) weighed over nine hundred adult bob-whites during a five year study in the Thomasville-Tallahassee region of Georgia and Florida, and found the birds to average between 160 and 170 grams, a very remarkable and stable figure considering the large number of individuals involved in this project. If all of our North American birds were to be studied in as complete and thorough a manner as Stoddard studied the bob-white, the problem of bird weight would be cleared up tremendously and the knowledge of American ornithology would be increased immeasurably. The weights of the other gallinaceous birds have not been studied or recorded to the extent they have been in the case of the bob-white and the ring-necked pheasant, but the following is a list of the weights of some of them taken from Gross(1937), Amadon(1943),

and Leopold(1944).

Species	Number weighed	Weight range
Rock Ptarmigan *Lagopus mutus*	9	450-500 grams
Ruffed Grouse *Bonasa umbellus*	7	480-520 grams
Wild Turkey *Meleagris gallopavo*	10	4000-5000 grams
Arizona Scaled Quail *Callipepla squamata pallida*	50	180-200 grams
California Quail *Lophortyx californica*	29	150-165 grams
Mountain Quail *Oreortyx picta*	30	240-250 grams
Mearn's Quail *Cyrtonyx montezumae mearnsi*	6	180-190 grams
European Partridge *Perdix perdix*	46	370-385 grams
Coast California Quail *Lophortyx californica vallicola*	48	185-195 grams
Texas Bob-white *Colinus virginianus texanus*	32	165-175 grams

It will be noted from a study and comparison of the weights of the gallinaceous birds that there is very little variation in average body weight.The largest variation occurs in the wild turkey with a range of 1000 grams,and the smallest in the bob-white,only about 10 grams.From this the following theorem is suggested:The larger the bird the greater the range in average body weight.If this is ever proved for birds in general,factors other than size will undoubtedly enter into the picture,but as yet not enough research and study have been conducted on the problem to draw such definite conclusions.

D. Passerines:

This extremly large order comprises twenty six families in North America alone and hundreds of species. More is known about the perching or song birds with regard to weight variation than any other order of birds. The passerines vary in size from the small kinglets and wrens to the comparatively gigantic raven, but the great majority of them are small birds. Since there are so many representatives in this order, the discussion on the average body weight range will be by families rather than by species.

I. Tyrannidae:

There are over twenty five species of flycatchers in the United States, but the weights of only a few are known. The commonest flycatcher, the phoebe, Sayornis phoebe, averages between 18.5 and 20 grams. Hartman (1946) weighed over fifteen adults and found them to average 19.4 grams with a fluctuation of only 1.4 grams on either side. The least flycatcher, Empidonax minimus, which is smaller than the phoebe, was found to average about 11.5 grams, the yellow bellied flycatcher, Empidonax flaviventris, averaged about 11.8 grams, and the wood pewee, Contopus virens, averaged 12.8 grams. All four of these birds are the smaller flycatchers, but no figures are available for the larger members of the family, such as the kingbird, Tyrannus tyrannus, the crested

flycatcher,Myiarchus crinitus,and the scissor-tailed flycatcher,Muscivora forficata,of the southwest.

2.Alaudidae:

This family includes the true larks,with the horned lark, Eremophila alpestris,being by far the commonest species. Montagna(1943) did much work on this species,and found over sixty adults to range in weight between 41 and 55 grams, with a mean average of around 48 grams.

3.Hirundinidae:

This family consists of the swallows and includes only about eight species found in the United States.With the exception of the purple martin,which reaches a length of nine inches,all are between five and seven inches long.Of the swallows that have been weighed,the rough-winged swallow, Stelgidopteryx ruficollis serripennis,seems to be the least heavy,averaging between 15.0 and 15.8 grams. Although no weights are available for the bank swallow,Riparia riparia, they probably do not differ greatly,since the two species are only distinguishable by the presense of a dark band across the breast of the latter.The commonest member of the swallow family,the barn swallow,Hirundo rustica erythrogaster,ranges in weight from 17 to 17.8 grams,judging from twelve adults weighed by Stewart(1927).The tree swallow, Iridoprocne bicolor,averages around 20 grams,according to

Hartman(I946),while the comparatively large purple martin, Progne subis,ranges from 44 to 50 grams.When it is recalled that the purple martin is only about two inches longer than the other swallows,it will be noted that there is a strikingly disproportionate average weight range,the purple martin being over twice as heavy as the other members of this family.

4.Corvidae:

This family is made up of the jays and crows mainly,but also includes the raven and the magpie.The blue jay, Cyanocitta cristata,seems to have a very steady weight range, as one hundred and seventy adults,weighed by Nice(I938), Amadon(I943),and Hartman(I946),averaged between 85 and 9I grams.The pinon jay,Cyanocephalus cyanocephalus,a bird of the Rocky Mountain region,ranges from I04 to II7 grams,and the Steller's jay,Cyanocitta stelleri,from I05 to II5 grams,yet both species are of the same length as the blue jay.Perhaps one of the greatest mass weighings that has ever taken place was one undertaken by workers in the United States Biological Survey,now the Fish and Wildlife Service,during the winter of I939 in Oklahoma.Dynamite sticks were placed in the trees of an extremly large communal roost,and when detonated killed an estimated I8,000 crows.From this large number of dead birds scattered over the region Ihmler and McMurry(I939) picked I000 at random and weighed them.Since the birds were weighed immediately after death there was no

weight loss from decomposition,and since only intact birds were chosen there was no weight loss through a wing,leg or head being missing.Upon sexing the birds it was found that 526 or 52.6 percent were males,and 474 or 47.4 percent were females.The birds were weighed in groups ranging from thirty five to sixty five birds per unit and the weight recorded in pounds per group.Upon completion of the job the total number of pounds was divided by the total number of birds weighed and an average weight in pounds per bird arrived at. There was found to be very little difference in the weights of the two sexes,the males averaging I.05 pounds per bird, and the females .95 of a pound per bird.If this figure is converted into grams it will be seen that the crow ranges in average body weight from 43I to 575 grams,a rather wide range.This figure corresponds to other less numerous crow weights recorded in the literature.As stated earlier,the raven,Corvus corax,is the largest passerine,being some four inches longer than the crow,but there are no available weight records for this comparatively rare bird.Also there could not be found any recorded weights for the magpie,Pica pica hudsonia,or the other species of jays and crows,found mainly in the western portion of the United States.

5.Paridae:

This family includes some thirteen species of chickadees,

titmice,and bush tits found within the continental limits of the United States.In some the weights have been rather fully investigated,in others no weights are recorded at all.Of the chickadees,the weights of the black-capped chickadee,Parus atricapillus,and the Carolina chickadee,Parus carolinensis, are the most recorded.One hundred and sixty five adult black-capped chickadees were weighed by Baldwin and Kendeigh (1938) and found to average between 10 and 12.1 grams.The Carolina chickadee,which is nearly identical with the black-capped except slightly smaller,was found to average between 9.2 and 10.8 grams.The tufted titmouse,Parus bicolor,was found by Hartman(1946) to range between 20 and 22.5 grams,an average weight range for fourteen adults.These three birds are the most commonly weighed of the Paridae,but a few figures are also available on some of the others.For example the Acadian chickadee,Parus hudsonicus littoralis,ranges between 10.5 and 11.8 grams,and the great titmouse,Parus major,and the blue titmouse,Parus caerulens,both natives of Europe,weigh around 18 and 11 grams respectively.

6.Sittidae:

This family includes the nuthatches of which only four species are to be found in the United States.The white-breasted nuthatch,Sitta carolinensis,by far the commonest of the four species,ranges in weight from 17.5 to 23.2 grams,

judged by thirty five adults weighed by Stewart(I937),and the red-breasted nuthatch,Sitta canadensis,from 9.2 to I0.5 grams. No recorded weights could be found for the two remaining species,the brown-headed nuthatch,Sitta pusilla,and the very small pigmy nuthatch,Sitta pygmaea.

7.Certhiidae:

This extremely small family is represented by only one bird in North America,the brown creeper,Certhia familiaris. Although this small bird has not been weighed to the extent that some of the others have,fourteen weight records for the species were found in the literature and all authorities were in agreement that the weight ranged from 7.6 to 9.I grams, a fairly steady average.

8.Troglodytidae:

There are some nine species of wrens found in the United States,but only three have been weighed and recorded enough to state an average body weight.Over four hundred and fifty adult house wrens,Troglodytes aëdon,were weighed by Esten (I93I) and Nice(I938),and were found to range between I0.5 and I3 grams.On the other hand the winter wren,Troglodytes troglodytes,weighs only between 9.I and 9.8 grams.The only other wren with enough recorded weights is the prairie marsh wren,Telmatodytes palustris dissaëptus,a bird of the west.

Myers(I928) weighed ten adults of this species and found them to range between II.4 and I3.6 grams.

9.Mimidae:

This family includes the mockingbird,Mimus polyglottos, the catbird,Dumetella carolinensis,the brown thrasher, Toxostoma rufum,and their relatives.The brown thrasher is by far the heaviest of the three,ranging between 60 and 70 grams, the mockingbird is next between 50.5 and 59.5 grams,and the catbird is last,averaging between 32 and 40.7 grams.In the western part of the country there are seven other species of thrashers,such as the California thrasher,Toxostoma redivivum, the sage thrasher,Oreoscoptes montanus,and the crissal thrasher,Toxostoma dorsale,but as they for the most part frequent desert country,no weights have as yet been recorded for these species.

IO.Turdidae:

This family includes the very familiar robin,bluebird, and thrushes.The weight range of these common birds is as follows,taken from Edson(I930),Poole(I938),and Hartman(I946).

Species	Number weighed	Weight range
Robin Turdus migratorius	I88	73-8I grams

Veery *Hylocichla fuscescens*	IO	28.5-34.5 grams
Wood thrush *Hylocichla mustelina*	8	48-52 grams
Bluebird *Sialia sialis*	36	28-33.5 grams
Gray-cheeked thrush *Hylocichla minima*	7	30-32.5 grams
Hermit thrush *Hylocichla guttata faxoni*	I2	28-32.5 grams
Olive-backed thrush *Hylocichla ustulata*	6	30.5-34 grams

II. *Sylviidae*:

Kinglets and gnatcatchers. This family of very small birds of from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches includes four species to be found in the United States. The golden-crowned kinglet, *Regulus satrapa*, has been weighed most, Hartman (I946) finding fourteen adults to range between 5.7 and 6.9 grams. The ruby-crowned kinglet, *Regulus calendula*, was found by the same authority to weigh between 6.I and 6.8 grams. No recorded weights are available for the remaining two species, the blue-gray gnatcatcher, *Polioptila caerulea*, and the plumbeous gnatcatcher, *Polioptila melanura*, a bird of the western part of the country.

I2.Motacillidae:

This family includes only two species found in North America,the American pipit,Anthus spinoletta,and Sprague's pipit,Anthus spraguei,both species from six to seven inches in length.There are no recorded weights for the latter bird, but the American pipit range in weight from I9.5 to 24 grams,judging from twelve adults weighed by Gross(I937).

I3.Bombycillidae:

As in the preceding family there are only two species to be found in North America,the cedar waxwing,Bombycilla cedrorum,and the bohemian waxwing,Bombycilla garrulus pallidiceps, Stewart(I937) weighed nineteen adults of the cedar waxwing and found them to range between 32 and 40 grams.Other weights of this bird agree with these figures. No weights are available for the bohemian waxwing.

I4.Laniidae:

The shrikes are represented by only two species in North America.The loggerhead shrike,Lanius ludovicianus,weighs between 46.5 and 50 grams,and the northern shrike,Lanius excubitor borealis,from 54 to 58 grams,but is about one inch longer than the preceding species.

I5.Sturnidae:

This family is represented by only one species,the starling,Sturnus vulgaris, which is not a native bird but was introduced from England.This bird has a rather wide weight range,from 59 to 96 grams,with a mean of 75 grams, as judged by eighty five adults weighed by Stewart(I927). Nice(I938) weighed sixty two adults and found them to average about 80 grams.It would be interesting to compare these weights with the starlings of Europe to see if possibly any changes in body weight have taken place since the introduction of the bird into this country.

I6.Vireonidae:

Although there are some thirteen species of vireos to be found in this country very few have been weighed,the weights of only three species being known.The blue-headed vireo,Vireo solitarius,ranges from I6 to I9 grams,the warbling vireo,Vireo gilvus,ranges from II to I5 grams in weight,and the commonest species,the red-eyed vireo,Vireo olivaceus,ranges from I5.5 to 2I grams.This is interesting in the fact that these three species are practically all the same size,yet their weight ranges in average body weight are different to the extent of almost I0 grams.

I7.Parulidae:

Of the some sixty-odd species of warblers to be found in North America,enough have been weighed to give a rough idea of the average range in body weight.With the exception of the yellow-breasted chat,Icteria virens, all are from four to six inches in length.The following is a list of some of the commoner warblers and their weight ranges taken from Esten(I93I),Heydweiller(I935),Stewart(I937),and Hartman(I946).

Species	Number weighed	Weight range
Myrtle warbler Dendroica coronata	34	I0.9-I3.8 grams
Black-throated green warbler Dendroica virens	32	8.5-9.5 grams
Oven-bird Seiurus aurocapillus	I0	I6.0-20.2 grams
Northern water-thrush Seiurus noveboracensis	7	I4.5-I9.4 grams
Redstart Setophaga ruticilla	I7	7.8-8.8 grams
Magnolia warbler Dendroica magnolia	I9	7.7-8.9 grams
Black-throated blue warbler Dendroica caerulescens	I2	9.2-II.I grams

Chestnut-sided warbler *Dendroica pensylvanica*	I3	9.0-I0.2 grams
Parula warbler *Parula americana*	I0	6.8-8.4 grams
Prothonotary warbler *Protonotaria citrea*	6	I0.5-II.4 grams
Cerulean warbler *Dendroica cerulea*	7	8.5-9.7 grams
Blackburnian warbler *Dendroica fusca*	8	9.9-II.2 grams
Pine warbler *Dendroica pinus*	5	8.7-II.8 grams
Yellow-breasted chat *Icteria virens*	I0	I9.0-26.0 grams
Yellow warbler *Dendroica petechia*	II	9.6-II.I grams
Cape-may warbler *Dendroica tigrina*	5	I0.0-II.0 grams
Tennessee warbler *Vermivora peregrina*	6	8.5-9.7 grams
Bay-breasted warbler *Dendroica castanea*	8	I0.0-II.I grams
Black-poll warbler *Dendroica striata*	I2	II.4-I3.9 grams

I8.Ploceidae:

This family includes two species,the house or English sparrow,Passer domesticus,and the European tree sparrow, Passer montanus.Both are introduced birds and are not true sparrows,but weaver finches.No weight records are available for the latter bird,since its range is only in the vicinity of St.Louis,Missouri,and it apparently is not too common even there.The English sparrow ranges in weight from 24.5 to 30.5 grams,a rather wide range for this comparatively small bird.

I9.Icteridae:

This fairly large family of some twenty two species found in the United States includes the blackbirds,orioles, cowbirds,and meadowlarks.The following is a list of their weight ranges,compiled from Esten(I93I),Stewart(I937), and Hartman(I946).

Species	Number weighed	Weight range
Meadowlark Sturnella magna	8	I20-I45 grams
Orchard oriole Icterus spurius	6	2I.5-24.5 gms.

Boat-tailed grackle *Cassidix mexicanus*	27	I48-I74 grams
Cowbird *Molothrus ater*	I50	40-48 grams
Red-winged blackbird *Agelaius phaeniceus*	44	35-55 grams
Bobolink *Dolichonyx oryzivorus*	7	32.5-36 grams
Bronzed grackle *Quiscalus versicolor*	5	I25-I32.5 grams
Baltimore oriole *Icterus spurius*	II	32.5-35 grams

20. *Thraupidae*:

The tanagers includes five species found in the United States, but only the average weight ranges of two of the species are known. The hepatic tanager, *Piranga flava hepatica*, a bird of the mountainous southwest, ranges from 30.5 to 38.5 grams, and the scarlet tanager, *Piranga olivacea*, the most familiar of the tanagers, ranges in weight from 27.4 to 29.6 grams.

2I.Fringillidae:

This very large family comprises over one hundred species,and includes the sparrows,buntings,finches,and grosbeaks.In all of them the bill is rather short and stout, adapted for a seed-eating diet.There is a good deal of material on the members of this family with regard to body weight,and the following is a list of some of the species and their weights,compiled from Stewart(I937),Baldwin and Kendeigh(I938),Nice(I938),and Hartman(I946).

Species	Number weighed	Weight range
Cardinal Richmondena cardinalis	505	40-45 grams
Tree sparrow Spizella arborea	675	I5-20.5 grams
Field sparrow Spizella pusilla	4I7	I0.5-I5 grams
Slate-colored junco Junco hyemalis	750	I8-23 grams
Fox sparrow Passerella iliaca	45	34-40 grams
Leconte's sparrow Passerherbulus caudacutus	I0	I2.3-I3.I gram

Chipping sparrow *Spizella passerina*	plus 2000	I0.0-I4.0 grams
White-crowned sparrow *Zonotrichia leucophrys*	325	23-30.5 grams
Snow bunting *Plectrophenax nivalis*	25	30-36.4 grams
Redpoll *Acanthus flammea*	I0	II.0-I2.8 grams
Harris's sparrow *Zonotrichia querula*	5	28.5-32.5 grams
Smith's longspur *Calcarius pictus*	5	26-28.5 grams
Indigo bunting *Passerina cyanea*	7	I2.5-I4 grams
Goldfinch *Spinus tristis*	500	II.5-I4.5 grams
Swamp sparrow *Melospiza georgiana*	60	I5.0-20.0 grams
Lincoln's sparrow *Melospiza lincolnii*	82	I5.8-20.6 grams

Grasshopper sparrow *Ammodramus savannarum*	5	I5.5-I8.5 grams
Song sparrow *Melospiza melodia*	plus I200	I8-24.3 grams
Purple finch *Carpodacus purpureus*	I60	23.2-25.9 grams
White-throated sparrow *Zonotrichia albicollis*	750	20.8-29.5 grams
Vesper sparrow *Poaecetes gramineus*	80	20.5-27 grams
Rose-breasted grosbeak *Pheucticus ludovicianus*	7	38-42 grams
Towhee *Pipilo erythrophthalmus*	223	38.5-4I.7 grams
Black-headed grosbeak *Pheucticus melanocephalus*	6	40-45 grams
Pine grosbeak *Pinicola enucleator leucura*	4	48-53 grams
Lapland longspur *Calcarius lapponicus*	II	27.5-30.5 grams

Savannah sparrow Passerculus sandwichensis	87	I7.5-I9 grams

It will be seen how much more is known about this family of birds with regard to the general average body weight, when it is realized that over 2000 adult chipping sparrows and over I200 adult song sparrows have been weighed. Many other of the species have also been weighed in large numbers, all of which makes it possible to better interpret the data and to draw some definite conclusions concerning the problem of weight variation in birds, as will be seen later.

This then concludes the general survey of the average body weights of the various groups of birds, and it is hoped that it not only gives the reader a general idea of bird weight for comparison sake, but also that it will serve to emphasize how much knowledge on the subject is really lacking, not only in the fact that in numerous species data are totally lacking as well as for entire families, but also in the fact that before the problem of average body weights of birds can be clarified, large numbers of birds have to be weighed in order to arrive at a good general average weight range.

Before passing on to the subject of weight variation with regard to age, it might be wise to examine the largest birds in the world, the Ratitae. These flightless birds are few in number but large in size, and all are characterized by the wings and shoulder girdles being much reduced, and by the fact that they have no keel on the sternum as have most birds. It was formerly believed that these were primitive characteristics which required these birds to be placed at the beginning of the table of the classification of birds, but it is now believed that these birds arose from flying ancestors, and that their present condition is due to degeneracy resulting in reduced or vestigial wings and massive size. The largest of living birds is the ostrich, Struthio camelus, which weighs around 225 pounds, but which may reach a weight of 300 pounds. Some of the extinct ratites reached even greater size, and Amadon(1947) has estimated their weights by comparing the skeletons of these extinct forms with the skeletons of the living ratites, whose weights are known.

Species	Body weight	Egg weight
Kiwi Apteryx australis	2.5 Kgms.	.371 Kgms.
Ostrich Struthio camelus	100 Kgms.	1.314 Kgms.

Emeu *Dromaeus novae-hollandiae*	47 Kgms.	.535 Kgms.
Cassowary *Casuarius uniappendiculatus*	42.5 Kgms.	.633 Kgms.
Rhea *Rhea americana*	20 Kgms.	.563 Kgms.
Elephant bird (extinct) *Aepyornis maximus*	435 Kgms.	7.762 Kgms.
Moa (extinct) *Dinornis agilis*	236 Kgms.	4.008 Kgms.

By examining this chart it will be seen, that based on a comparison with living ratites, the weight of the largest known bird, *Aepyornis maximus* of Madagascar, is estimated at 435 kilograms or 965 pounds, and the weight of the largest moa, *Dinornis agilis*, as 236 kilograms or 520 pounds, both being truly tremendous birds when compared even with a giant like the ostrich. It will also be noted that the kiwi, *Apteryx australis*, a flightless bird of the islands of New Zealand, and which weighs only about 2.5 kilograms, lays a huge egg of about 0.317 kilograms, according to Amadon(1946) the largest relative to the weight of the bird in the entire class Aves. The rhea, *Rhea americana*, also lays a very large egg but it does not rival that of the kiwi in comparison.

The eggs of the emeu, Dromaeus novae-hollandiae, and the two large extinct ratites are rather small in comparison with their sizes, but are nevertheless huge eggs.

Weight Variation with Age:

In examining the factors which influence the body weight of birds,one of the first to come to mind is naturally age. The previous section,dealing with a general survey of the average body weights in birds,considered only the adults, and did not take into consideration eggs,nestlings,and immatures.Naturally any bird before reaching the adult stage, characterized by size,coloration,and sexual maturity,must pass through these three stages some time during its life span,and the weight of a bird during these three stages is quite variable.

A.Egg:

The dimensions,coloration,and shapes of bird eggs have been known for many years,and before various laws were passed prohibiting it,oölogy,or the collection of bird eggs,was both a pleasurable and profitable hobby and business to many.The weights of the eggs collected,however,were very rarely if ever taken,and it has only been in recent years with the advancement of life history studies that egg weights have been recorded.Thus through a sad lack of data,this phase cannot be covered in too thorough a manner,but there is a little material on the subject which can be studied and analyzed.For example the weight of an egg when laid by the female bird is considerably heavier than just before the

young bird is hatched.The following table modified after Walkinshaw(1940) on his study of the sora rail,Porzana carolina,illustrates this point.

Egg	May 23	June 8-10	June 9-11
1	7.3 Gms.	6.8 Gms.	5.8 Gms.
2	7.3 Gms.	6.7 Gms.	5.8 Gms.
3	7.6 Gms.	6.9 Gms.	5.8 Gms.
4	7.5 Gms.	6.7 Gms.	5.3 Gms.
5	6.5 Gms.	5.5 Gms.	5.0 Gms.
6	6.9 Gms.	5.8 Gms.	5.0 Gms.
7	7.1 Gms.	6.6 Gms.	5.8 Gms.

From this table it will be seen that all seven eggs decreased in weight during a little over a two week incubation period ,due to the growing embryo taking its nurishment from the food reserve contained in the egg. Another interesting fact brought out by the examination of this table is the fact that all the eggs do not weigh the same,although they are all from the same set.One hundred and twenty eight eggs from sixteen nests were also weighed by the same author and were found to vary from 6.5 to 10.25 grams,with a mean average of 8.3 grams.Why this should be is probably dependent on several factors such as thickness of the shell,amount of albumen and yolk present,condition of the female,clutch number,species,natural selection,or even

BOSTON UNIVERSITY

artificial selection as in the case of different strains of domestic fowl.Eggs of other birds have been noted to vary as much if not more than the eggs of the sora rail.Gross(1937) for example,examined six egg sets of the common eider, Somateria mollissima,containing twenty four eggs,and found them to range from a low of 85.4 grams to a high of 111.5 grams,a difference of almost 26 grams.Palmer(1940) found the eggs of the semipalmated plover,Charadrius hiaticula semipalmatus,to range from 8.7 to 10.3 grams,the eggs of the arctic tern,Sterna paradisaea,from 16.5 to 17.6 grams,and the eggs of the hudsonian curlew,Numenius phaeopus hudsonicus, from 42.4 to 48 grams.Even the relatively small eggs of the passerines vary to a degree.Amadon(1943) found twenty one eggs from twelve sets of the eastern field sparrow,Spizella pusilla pusilla,to vary from 2.88 to 3.20 grams,and forty six eggs from fifteen sets of the cardinal,Richmondena cardinalis, ranged from 7.7 to 8.9 grams.It might be assumed that the heavier the egg the heavier the consequently hatched young bird,but an examination of Walkinshaw's table on the sora rail does not substantiate this theory whatsoever,for it will be seen that an egg which weighed 6.6 grams on June 8-10 hatched forth a young weighing 5.8 grams,while an egg weighing 6.7 grams,or .1 of a gram heavier on the same date,hatched forth a young weighing only 5.3 grams,or .5 of a gram lighter. Just what underlies phenomena such as these is not known.As

stated earlier,the key to the solutions will be found undoubtedly in the metabolism and physiology of the female bird,plus other factors,but as avian physiology is even less known and understood than bird weight,no theories can be advanced at this time.

Heinroth(1942),a German ornithologist,spent considerable time studying the sizes of bird eggs in relation to the size of the bird,and came to the following conclusions:

(I).Large birds,in general,lay relatively smaller eggs than small birds,and

(2).Many groups have peculiarities of their own,thus kiwis lay very large eggs,parasitic cuckoos very small ones, and precocial birds lay larger eggs than altricial birds of the same size.

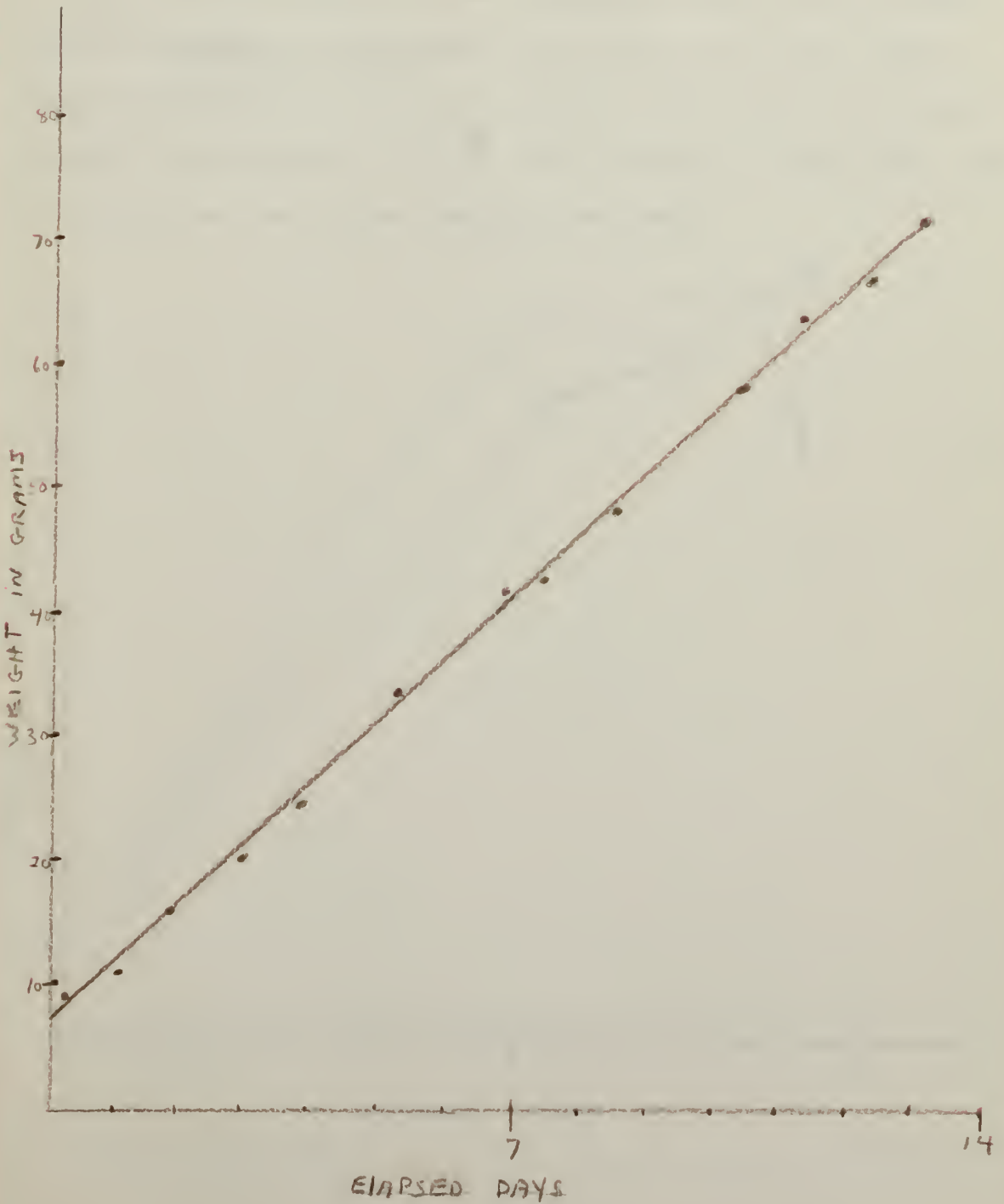
Although egg weight has little or no effect on the future weight of the adult,providing of course it is not abnormal, it is nevertheless important and may hold the clues to the solutions of more problems in ornithology than seem evident at the present time.

B.Nestling:

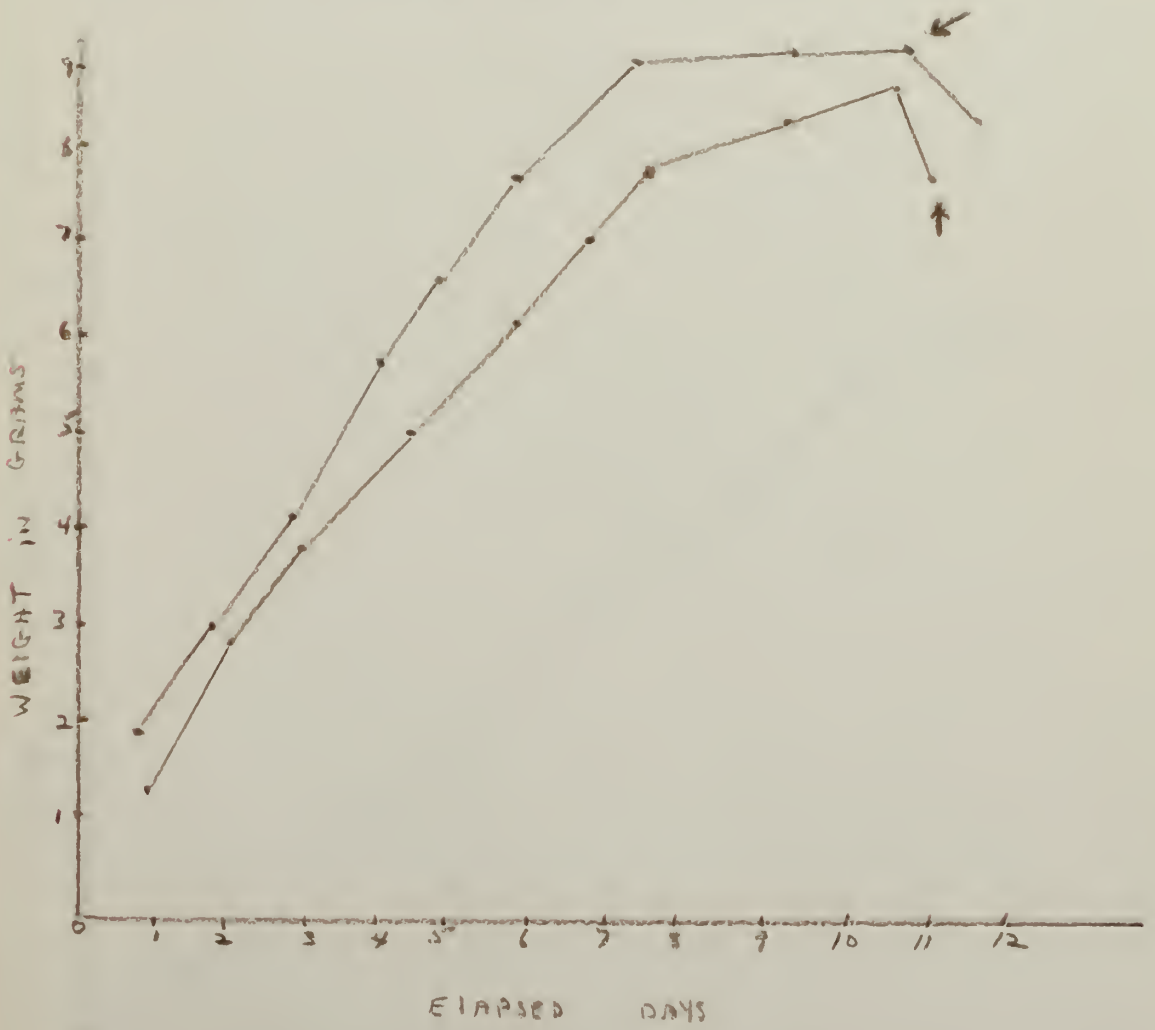
The nestling period in a bird's life may be defined as the time between the pipping or hatching of the egg and when the bird acquires immature plumage and leaves the nest.This period ranges from several weeks or even months in some of the altricial birds to only a few weeks in the case of precocial birds,which are able to run,hide,and feed more or less for themselves very soon after hatching.

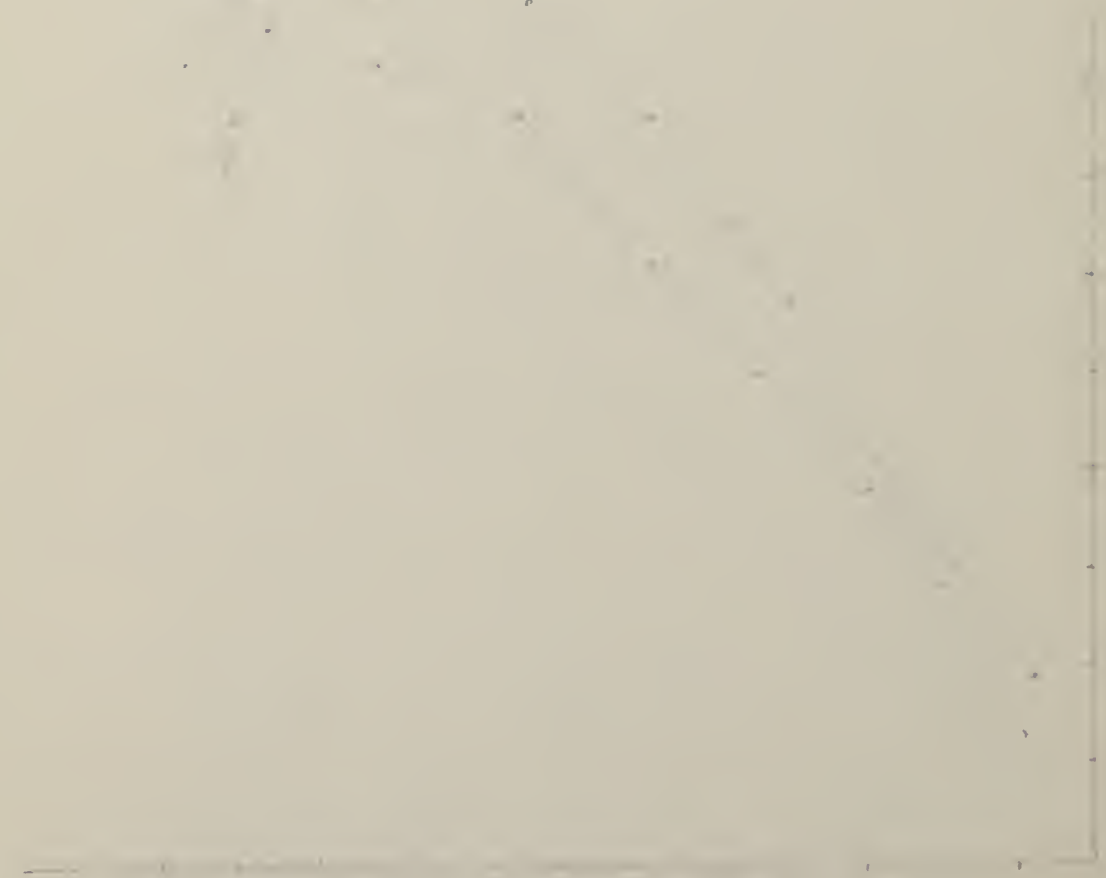
As soon as the young of altricial birds are hatched they are naked,helpless,and at the lowest weights in their lives. Walkinshaw(1937) recorded the weights of three newly hatched Leconte's sparrows,Passerherbulus caudactus,as being 1.2, 1.7,and 1.8 grams respectively,and two newly hatched chipping sparrows,Spizella arborea,as being 1.6 and 1.5 grams respectively.Baldwin(1888) weighed two newly hatched bush-tits,Psaltriparus minimus,and found them to weigh only .65 and .72 grams respectively.Other observers have recorded low weights for newly hatched young,the weight depending on both the species and the size of the bird.Sexual variation does not enter into the picture for the first few days,nor does temperature or any of the other factors to be discussed later.After the low point of the first day the weight increases rapidly until the bird is ready to leave the nest, but there are some exceptions.The following growth curve of a young eastern nighthawk,Chordeiles minor,taken from Fowler(1946),shows a steady almost proportional increase in

body weight throughout the nestling period, this bird incidentally being precocial.

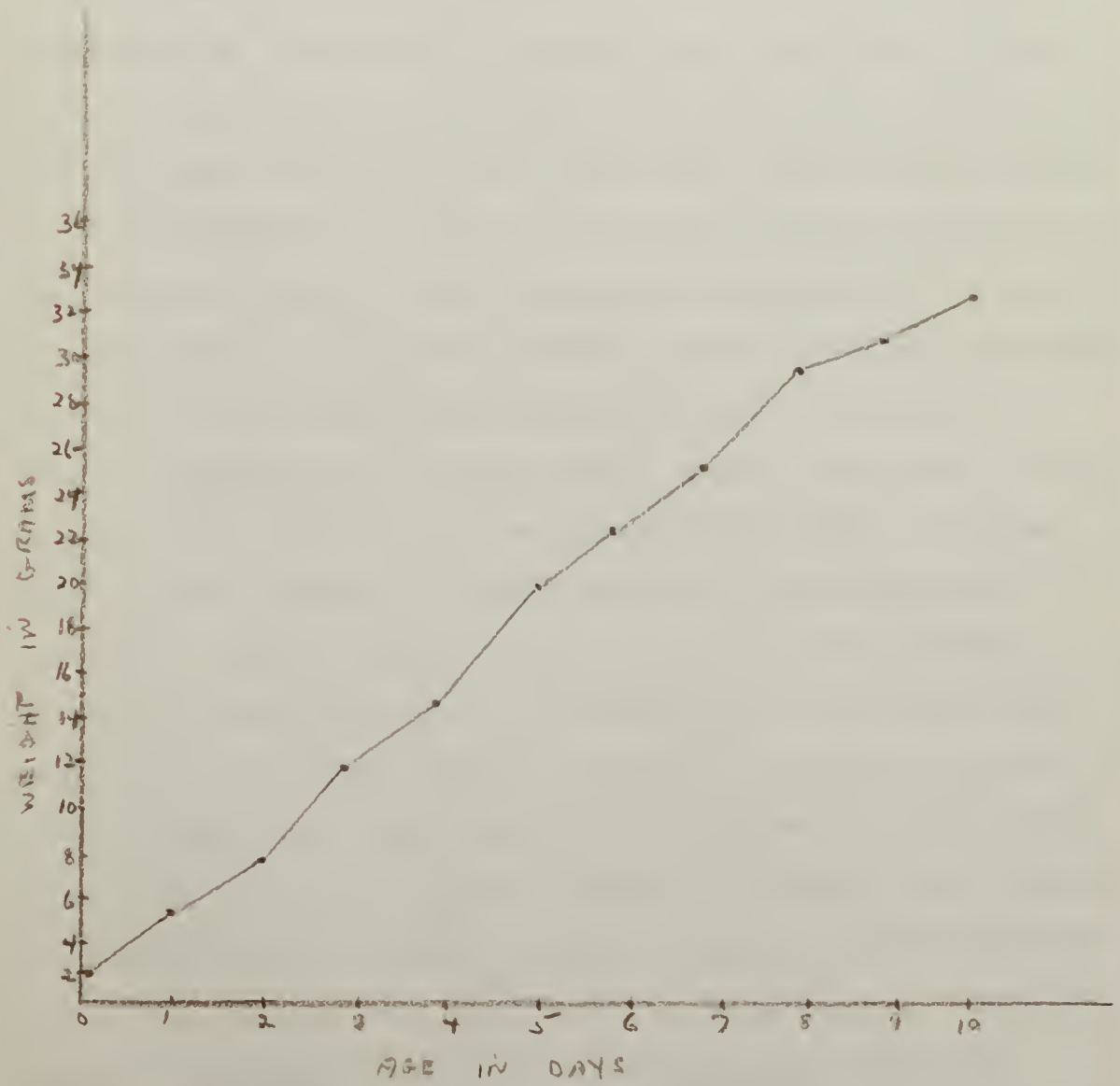


Other species do not show such a steady straight line weight increase graph as does the nighthawk, as illustrated by the following graph of two nestling black-throated green warblers, Dendroica virens, which are altricial birds, taken from Pitelka(1940). Note that in one of the birds the weight dropped one day before it left the nest, and in the other bird it dropped one day after leaving the nest.





On the other hand, the average rate of daily weight increase of a young eastern cowbird, Molothrus ater ater, as taken from Friedman(1929), seems to be intermediate between the two. The cowbird does not build a nest of its own, but is a social parasite, laying its eggs in the nests of many species of smaller birds, particularly warblers, vireos, and sparrows.



These three graphs are by no means to be taken as typical weight graphs of precocial, altricial, and social parasite nestlings, but they do illustrate the difference in three species which happened to fall into these categories. When more data are available it will undoubtedly be found that there is a difference to some degree even in individuals as well as in species.

As mentioned, some nestlings exhibit the interesting phenomenon of decreasing in weight after a variable period of time in the nest. This apparently does not occur in all species, but in those in which it does the weight drops several grams a few days before the young leave the nest. Edson (1930) suggests that there is possibly some correlation between the excess of weight reached by the young and the need of feather development. By this he apparently means that certain birds, such as swallows, which feed in flight, need a longer occupancy of the nest for the feathers to grow than do birds such as wrens, which can hop around on bushes and more or less feed on the ground. The theory comes to mind that perhaps the parents purposely slacken off on the feeding a few days before the young leave the nest as more or less of a 'hunger incentive' to get them to desert their birth place. Whatever the cause, this interesting topic is certainly worthy of further investigation and study, for it is indeed unusual, although it has only been observed in some of the passerines to date. The following chart of an eastern chipping sparrow, Spizella passerina

passerina, as taken from Weaver(1937), illustrates this in tabular form.

Age in days	Weight in grams
-I	I.6
I	2.85
2	4.4
3	5.3
4	7.5
5	9.2
6	I0.0
7	I0.8
8	I0.5
9	I0.4
I0	9.8 (able to fly)
II	9.5 (left nest)

Although most birds are fed almost within hours after they have hatched, with a consequently gradual increase in body weight, Webster(1942) made an interesting observation in the case of the black-oyster-catcher, Haematopus bachmani, where the young birds were not fed for from thirty six to forty eight hours after hatching, with a consequent decrease in weight for the first two or three days. Whether or not this is true of the precocial birds in general is not known, nor why it occurs is not known, but it certainly offers opportunity for some

interesting research on the problem.Hoyt(1944) studied three nestlings of the pileated woodpecker,Hylatomus pileatus,from the day of hatching to the day they left the nest,and in all three found a steady day by day weight increase up to and including their first flights from the nest-tree,the weights of the three young increasing from 20.4 to 244.4 grams,36.6 to 218.7 grams,and 29.9 to 227.3 grams over a period of twenty six days.

Comparative studies made in the growth of nestling raptores by Sumner(1929) show long periods of occupancy of the nest and tremendous weight increases before the birds left. A golden eagle,Aquila chrysaëtos canadensis,occupied the nest for over ten weeks and in that time increased from 108.7 grams at hatching to 4250 grams on the day it left the nest.The screech owl,Otus asio,increased from 20 to 140 grams over a period of thirty days,the western red-tailed hawk,Buteo borealis calurus,from 75 to 990 grams over a period of thirty seven days,the sparrow hawk,Falco sparverius,from 15 to 105 grams in twenty six days,and the horned owl,Bubo virginianus pallescens,from 37.5 to 773.7 grams in thirty six days.These tremendous weight gains in the birds of prey may be due in part to the relatively large meals they receive,the type of food,namely animals,fish,or other birds,or to the long rather inactive period in the nest.

It will be noted that as far as nestlings are concerned many interesting features of weight are exhibited,and no two groups of birds,perhaps even species,are exactly the same with regard to weight-growth curve,occupancy of the nest,decrease or increase of weight,and other factors.There unfortunately are not sufficient data to draw any concrete conclusions on nestling weight in general,but at least what information is available opens up many interesting possibilities for further investigation on the subject.

C. Immature:

Immature birds are considered to be those which have left the nest and are living more or less independently of their parents.They are for the most part birds of the year and are characterized by being sexually immature and by having immature plumage.In nearly all cases immature birds weigh less than do the adults.McIlhenny(I937) for example weighed thirty immature boat-tailed grackles,Cassidix mexicanus,and found them to weigh only a little over three-quarters as much as the adults.Walkinshaw(I940)found eight immature sora rails, Porzana carolina,to average 80 grams,against 85 grams for eight adult males,a fairly close figure but still less than adult weight.On the other hand he found five adult females to average 7I.9 grams against four immature females weighing

72.7 grams.This is rather unusual and may indicate either a faulty method of analysis or an inadequate amount of data,or both.Although much data are lacking on the weight of many species with regard to immature weight versus adult weight,it appears that in addition to the female sora rail mentioned above,only one species consistently weighs more as an immature than as an adult,the catbird,Dumetella carolinensis.Several authors have noted this unusual case,notably Baldwin and Kendeigh(1938),who weighed fifty three adults and forty immatures and found the immatures to average between 5 and 10 grams heavier.Undoubtedly a few other species will also fall into this category when more data on many more species are available.Since it is the general rule among birds that the immatures weigh less than the adults,the question immediately comes to mind,"When is adult weight reached by the immatures"? From evidence gathered for a number of species by the authors recently mentioned,it apparently is the rule that this difference in weight is erased by September,or just before migration commences,but it may persist for a month or two longer.In most birds at least,this difference is erased certainly by the spring migration when last year's immatures return north as this year's adults.In birds that take over a year to mature,such as hawks,eagles,some gulls,and others,this difference may not be erased for several years,but this is pure speculation as there is no concrete evidence on the subject,although it is known that these birds do not acquire

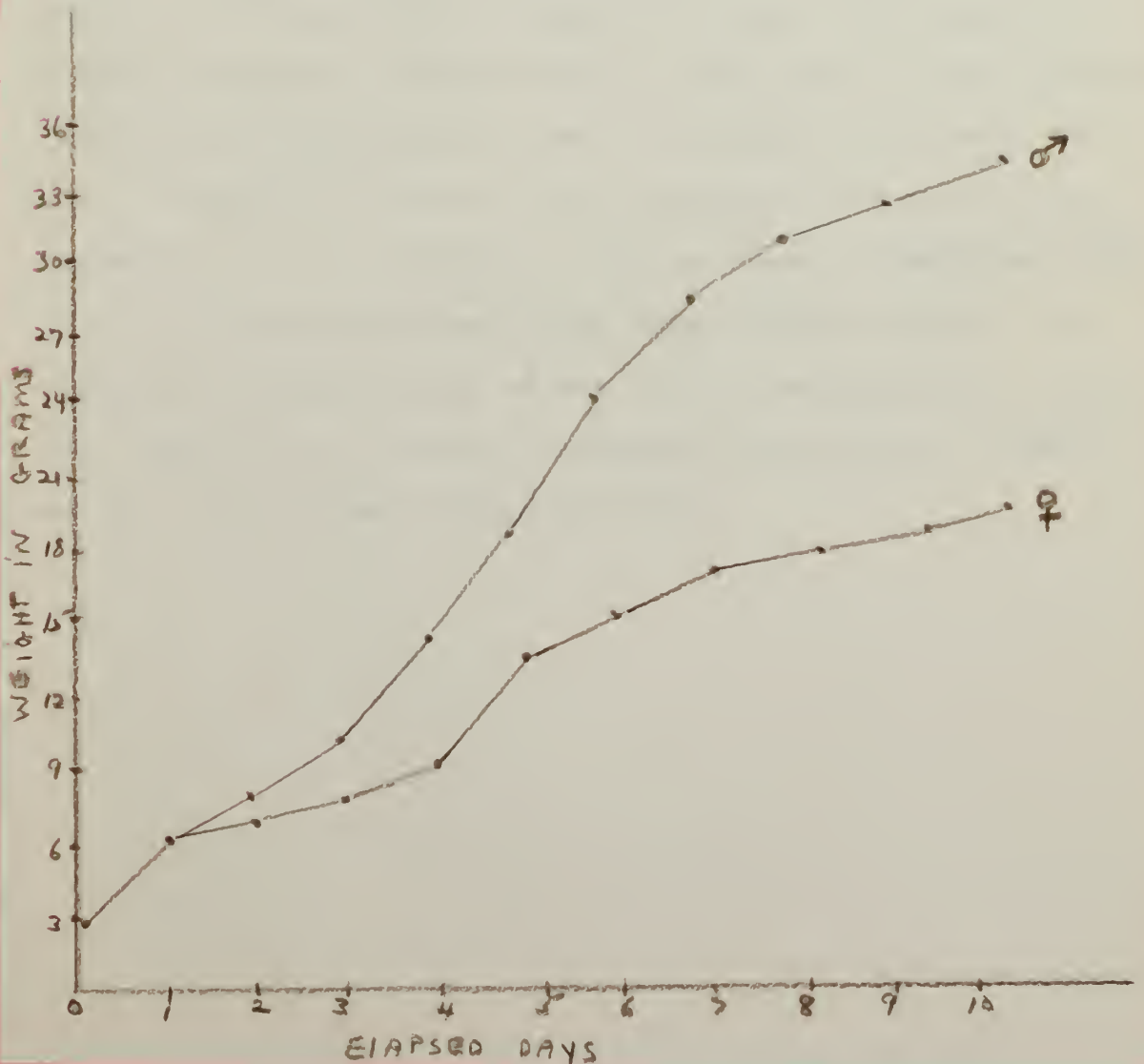
adult plumage for several years,as long as six years often in the case of the bald eagle,Haliaeetus leucocephalus.

Weight Variation with Sex:

It has been known for some years that male and female birds as a rule are not the same size,and hence thought not the same weight.As more and more birds were weighed,however, it sonnbecame apparent that birds fall into one of three categories with regard to sexual weight;group A,in which the male and female are of approximately the same weight,group P, in which the male is significantly heavier than the female, and group C,in which the female is significantly heavier than the male.The majority of birds are relatively easy to sex at sight,especially in the breeding season,as the male is the more brilliant,whereas in many instances the female is of a somber nondescript coloration.Perhaps the only exceptions to the rule,in North America at least,are the phalaropes and the belted kingfisher,Megaceryle alcyon,in which the females are the more gaudily attired in the breeding season.In many birds , however,visual sexing is impossible because of the similarity between the two sexes,such as the sparrows,flycatchers,wrens, and others.Baldwin and Kendeigh(1938) give a clue as to how to sex such birds as these when it is certain that only the female incubates the egg.If down feathers are absent in the ventral apteria the bird is a female,if down feathers are present in the ventral apteria the bird is a male.This character is useful however only during the breeding season.

All other factors being equal,sexual variation in size and weight is a secondary sexual characteristic,and the

difference then is genetic for the most part.If this is true one would expect sexual differences to show up rather early in life,and there is convincing evidence,in some species at least,that the difference in weight between the sexes begins early in the nestling stage.The following graph,taken from Williams(I940),shows the daily weights of some twenty five male and twenty five female red-winged blackbirds,Agelaius phaeniceus,whose identity was known throughout the nestling period.



From this graph it will be noted that the average weight of the red-wing nestling at hatching is approximately 3 grams. At about the third or fourth day a bimodal distribution becomes clearly apparent,forming a break which definitely separates a light from a heavy group,and this break remains in the graph,increasing in extent with increasing age.Williams dissected sixteen birds from these two groups,and in every case the females fell into the light group and the males into the heavy group.It thus seems quite apparent that there is complete differentiation between the sexes with regard to weight during nest life,at least in the case of the red-winged blackbird.Whether this is true of all species in which the male or female is heavier is not known,as this is the only experiment of its kind that could be found in the literature. If it is ultimately found to be true for the majority of birds,the distinguishing of sex in the nestling stage would be a great aid in breeding censuses ,distribution studies, and the study of sex ratios in birds.

Group A:Birds in Which the Sexes Are of Approximately the Same Weight:

Most of the birds which fall into this group are those in which the male and female differ not too greatly in plumage, there of course being exceptions.The downy woodpecker, Dendrocopus pubescens,for example,shows very little if any sexual discrepancy,and the only field characteristic for distinguishing the sexes is the presence of a small patch of red on the nape of the male.The two sexes of the chipping sparrow,Spizella passerina,look exactly alike in the field and weigh practically the same.The same is true for other identical species such as the red-eyed vireo,Vireo olivaceus, the white-breasted nuthatch,Sitta carolinensis,the field sparrow,Spizella pusilla, the red-eyed towhee,Pipilo erythropthalmus,and several others.On the other hand male cardinals,Richmondena cardinalis,bluebirds,Sialia sialis, and the English sparrow,Passer domesticus,are distinguished from the females by their somewhat more gaudy coloration,but the weight difference between the sexes is only about one gram at the most.

Group B: Birds in Which the Male is Significantly Heavier Than the Female:

The majority of birds fall into this category, which include the ducks, most of the water and shore birds, and a large number of passerines and non-passerine land birds. In all of the ducks and most of the water and shore birds the males are more brilliantly colored than the females, but in the land birds it also includes species in which both male and female are similarly colored. To mention a few of the more familiar land birds which fall into this category, and on which there is sufficient information, there are the song sparrow, Melospiza melodia, the slate-colored junco, Junco hyemalis, the cowbird, Molothrus ater, the brown thrasher, Toxostoma rufum, the mourning dove, Zenaidura macroura, the black-capped chickadee, Parus atricapillus, the hairy woodpecker, Dendrocopus villosus, the goldfinch, Spinus tristis, the flicker, Colaptes auratus, and the starling, Sturnus vulgaris.

Group C; Birds in Which the Female is Significantly Heavier Than the Male:

This group contains comparatively few birds, and from the data available consists of the following; the Raptores in general, the catbird, Dumetella carolinensis, the house wren, Troglodytes aedon, the bob-white, Colinus virginianus, and the robin, Turdus migratorius.

The accumulation of a greater volume of records may possibly change the relative status of the sexes in a few species now in any one of these three groups, and will also increase the lists tremendously as comparatively few sex weights are known, but the above groupings at least give the reader the fact that there is a discrepancy between the sexes as far as weight is concerned. The fact must be kept in mind, however, that a female with eggs is much heavier than one without, and that during this period of the year she may equal or even surpass the male in body weight in a large number of species, especially in species where the weight difference between the sexes is not too great when the female is without eggs.

Weight Variation With the Time of Day:

That birds vary in weight at different hours of the day and night has long been supposed,although actual quantitative study of such variation is not too great.It has long been known in biology that diurnal organisms lose weight at night due to katabolic processes taking place in the body, plus the egestion of feces,and this is true for all diurnal birds on which data of this nature are available.For example Taber(1928) determined that mourning doves,Zenaidura macroura, lost in weight during twelve hours at night an amount equal to between eight and nine per cent of their early morning weight,and also found for miscellaneous records of some fifteen species this loss to average approximately eight per cent.Stewart(1937) has made an extensive study of this subject,and states that an overnight weight loss of about ten per cent is sustained in small birds,but that this becomes less in larger birds,being only five per cent,for example,in the bob-white,Colinus virginianus.If diurnal birds lose weight at night,as has been proved they do,it is in the very early hours of the morning,before feeding is begun,that birds are at their low point in weight during the entire twenty four hour span.In other words,if a bird's weight were to be graphed from the time it retired in the evening to the time it began feeding again the next morning,the weight line on the graph would show a slow but steady drop hour by hour,even if

slight.In studying weight fluctuation during the hours of daylight,however,it is immediately seen that it is not as simple to explain as it was at night.The following chart, taken from Stewart(1937),shows the hourly weight rhythm as exhibited by one hundred and sixty five goldfinches,Spinus tristis tristis,between the hours of 7:00 A.M. and 5:00 P.M.

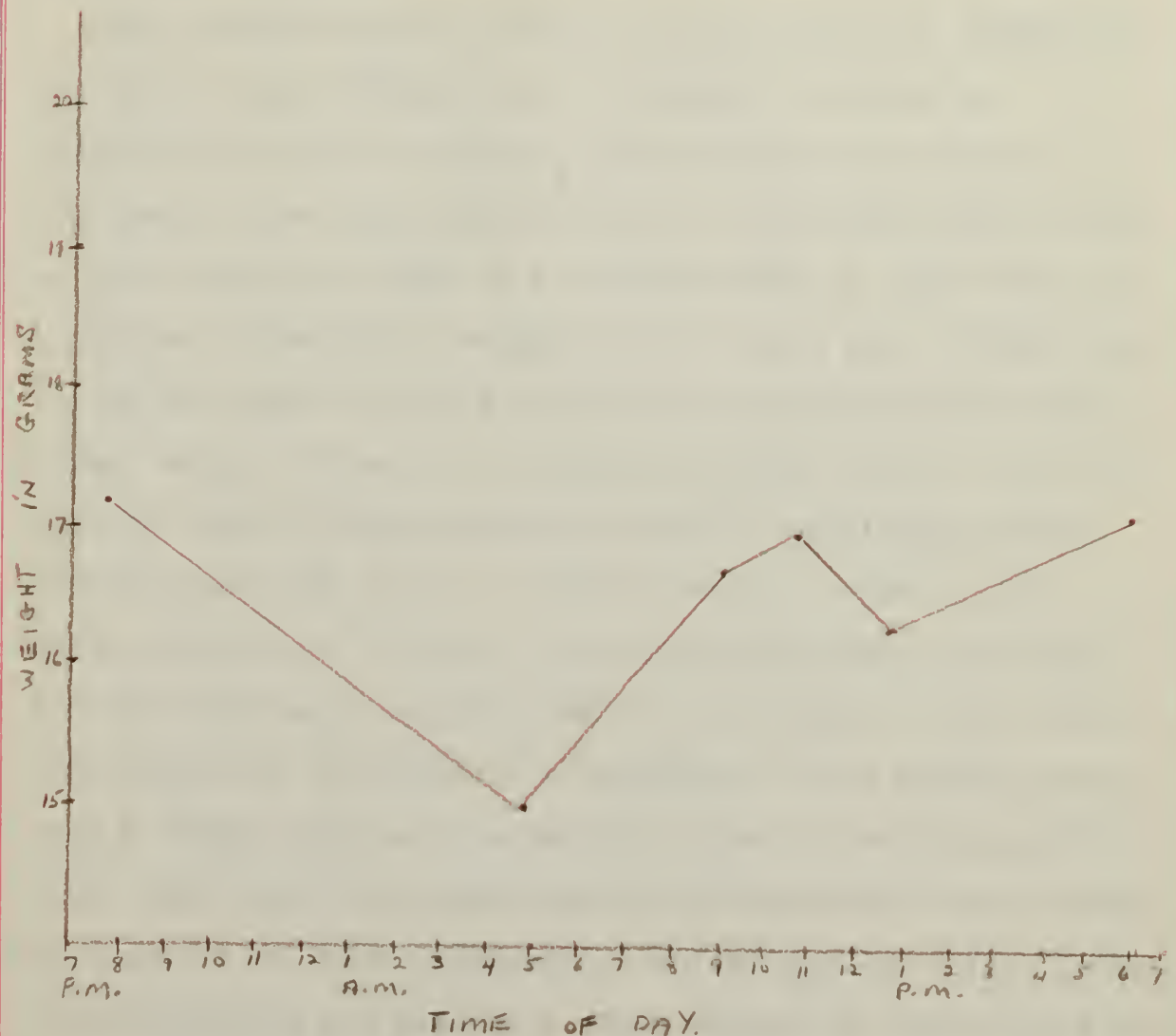
Hour	Number weighed	Average weight
7:00 A.M.	6	12.04 grams
8:00 A.M.	13	12.33 grams
9:00 A.M.	8	12.42 grams
10:00 A.M.	11	12.68 grams
12:00 noon	23	12.73 grams
1:00 P.M.	58	12.67 grams
2:00 P.M.	11	13.10 grams
3:00 P.M.	15	13.33 grams
4:00 P.M.	7	12.25 grams
5:00 P.M.	9	13.11 grams

This chart clearly shows a low point in the morning, a gradual rise until about noon,a period of slack in the early afternoon,and then another rise until dusk.The increases,one in the morning and the other in the late afternoon,can be explained by the fact that the birds were feeding and hence gained weight.The slight drop in weight around mid-day was due to the fact that the birds do not feed at this time,thus utilizing energy and hence weight from the

morning's foraging.Nice(1934) found the same thing to be true in her study of seven hundred and thirty weights of the song sparrow,Melospiza melodia,the weight decreases in the late afternoon amounting to somewhat less than five per cent of the total body weight.Other workers who have studied bird weights during different periods of the day get approximately the same results.For example,Linsdale and Sumner(1934) found upon examining the records of four hundred and sixty four golden-crowned sparrows,Zonotrichia albicollis,which they weighed in California,that the greatest weight is reached quite late in the afternoon,or shortly after the mid-day period of inactivity,when feeding is again begun.It might be assumed that weight would increase rapidly once feeding began and would continue to increase until feeding is stopped some hours later,but this is not the case.Reliable information from several of the authors recently mentioned seems to strongly indicate that birds as a rule maintain a moderately full stomach at all times when feeding has gotten under way,and do not alternately empty and fill it to capacity as might be supposed,so that once the stomach is filled during the morning feeding there is relatively little change until the mid-day rest period,with the same thing occuring in the afternoon feeding period.Experiments with various passerine species have shown that from one and a half to two hours is an adequate length of time to permit a small bird to fill its digestive tract and begin egestion of

indigestible material.For these reasons was it mentioned earlier that there is no such thing as a true weight of a bird,for there would undoubtedly be much difference of opinion as to what time of day it should be taken.Some might favor the evening bird with a well filled stomach,others the morning bird with the minimum of ingested food,while still others would want to strike a mean average between the two extremes.Only when a large number of birds are weighed at different times of the day can the mean or general average weight be accurately represented,and the larger the number of specimens involved the nearer to the accurate weight range.

The following graph shows a twenty four hour period in the life of a typical passerine bird,in this case the song sparrow,Melospiza melodia,as modified after Baldwin and Kendeigh(I938).Note that the weight declines steadily during the night until about 5:00 A.M. when it begins to rise,the bird now feeding.Around I0:00 A.M. the curve begins to slacken off because of the moderately filled stomach maintenance, drops around I:00 P.M. while the bird rests and does not feed, and then rises again until the bird retires for the night.



Undoubtedly different species vary slightly from the above graph,but it does give the overall picture of weight ascent and decline over a twenty-four hour period. This graph is not intended to be a typical all year round graph even for the song sparrow,for quite naturally factors such as amount of feeding,lengths of daylight and darkness

throughout the year,and other factors enter which would alter the graph slightly.

The problem of the variation in the weight of birds with the time of day raises several questions on which no information could be found in the literature.For example,is the twenty four hour weight curve of a nocturnal bird,such as an owl,opposite to that of a diurnal bird? In other words do nocturnal birds show a weight rise at night and a weight fall during the day? What part does body metabolism really play in normal weight variation in birds? Nice(1938) gives a hint by stating that the respiration quotient of relatively active and feeding birds is I.O or thereabouts,but when it goes below this figure the bird is metabolizing stored body fat. How does the daily weight curve of a bird with a crop differ from that of a bird without a crop?What do the weight curves over a twenty four hour period look like in the many types of birds other than the passerines and non-passerine land birds? The answers to these intriguing problems must wait for further experimentation and study,but their mention at least gives one a general idea of the many problems and complexities involved in this topic.

Weight Variation With the Amount of Food Consumed:

Weight variation in birds in proportion to the amount of food eaten would seem to be of great importance,but data on the subject minimizes its effectiveness.According to Nice(1938), experiments on the percentage of food eaten by birds in relation to their weight have been carried out in Europe for a number of years,with two main conclusions resulting.First, the colder the weather the greater the food consumption,and secondly,the smaller the bird the more in proportion to its size does it eat.The following table,taken from Nice(1938), clearly shows the inverse relation between size and relative food consumption.It will be noted that the smaller birds have a relatively larger surface area than the larger birds,and hence lose more heat.The great majority of the birds mentioned in this table are European birds,on which a large amount of this type of investigation has been done.

Species	Weight	Percentage weight of food
Falconiformes		
Common Buzzard *Buteo buteo*	855-900 grams	4.5 per cent
Kestrel *Falco tinnunculus*	200 grams	7.7 per cent
Galliformes		
Domestic Fowl *Gallus domesticus*	1800 grams	3.4 per cent

Charadriiformes		
Lapwing *Vanellus vanellus*	195 grams	7.8 per cent
Dunlin *Calidris alpina*	114 grams	8.5 per cent
Columbiformes		
Pigeon ?	516 grams	5.4 per cent
Pigeon ?	360 grams	6.5 per cent
Dove ?	160 grams	8.6 per cent
Western Mourning Dove *Zenaidura macroura marginella*	100 grams	11.2 per cent
Strigiformes		
Tawny Owl *Strix aluco*	442-475 grams	5.0 per cent
Little Owl *Athene noctua*	164-172 grams	5.5 per cent
Passeriformes		
Blackbird *Turdus merula*	118 grams	7.3 per cent
Song Thrush *Turdus philomelos*	89 grams	9.8 per cent
Redbreast *Erithacus rubecula*	16 grams	14.7 per cent
Chaffinch *Fringilla coelebs*	22 grams	13.2 per cent
Great Titmouse *Parus major*	18 grams	26.0 per cent

Blue Titmouse Parus caeroleus	II grams	30.0 per cent
Goldfinch Carduelis carduelis	I3 grams	I7.5 per cent

It will be noted in examining this table that there is quite a discrepancy in the percentage weight that makes up the food consumed in the various species mentioned,but all other factors being equal,this daytime weight increase in weight is lost at night so that there is no appreciable gain in weight from day to day.

As mentioned in the preceding section,birds eat fairly heavily during the morning and afternoon feeding periods,but this is to make up for the weight lost during the night and may be an efficient factor for safety in the life of the bird, since it better prepares the bird to tolerate any unfavorable weather conditions which might arise.It will also be recalled that most birds do not fill their stomachs to capacity,but maintain a relatively full stomach during the day through both the ingestion of food and the egestion of feces.According to Stewart(I937),the amount of food in the stomachs of twenty five adult song sparrows,Melospiza melodia,English sparrows, Passer domesticus,starlings,Sturnus vulgaris,and white-breasted nuthatches,Sitta carolinensis,averaged about I.5 per cent of the total body weight.If as much is in the small intestine and a similar amount in the large intestine,then roughly about 4.5 per cent of the total body weight may

represent unassimilated material.Stewart(1937) also weighed single excrement droppings from these small birds and found them to average a little less than 0.5 per cent of the total body weight.

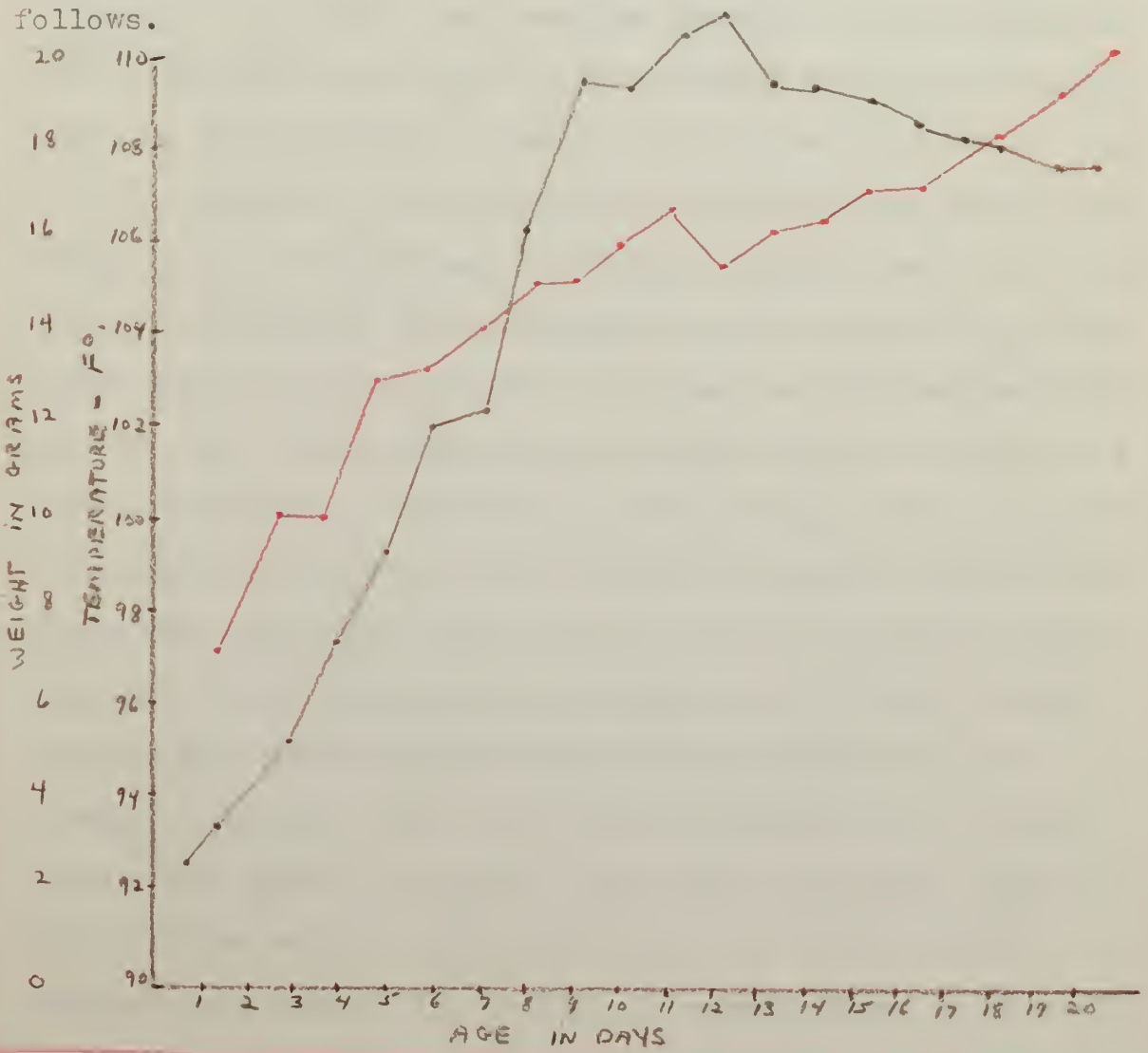
It might also be expected that when a bird comes repeatedly to a banding trap to obtain much of its food,in other words develops a "trap habit",there would be an interference in the weight physiology of the bird,but the following table,taken from Baldwin and Kendeigh(1938),on the variability in weight of adult chipping sparrows,Spizella passerina,correlated with the number of times captured and weighed,shows it to be of little signifigance.

Times weighed	Number of birds	Weight in grams
2-6	30	12.4
7-10	24	12.4
11-20	15	12.2
21	4	12.2

As will be noted,the weight deviation in a bird caught repeatedly in the traps coming for food is less than half a gram on either the plus or minus side of the average weight of the species.The same thing applies to other species of sparrows and other birds repeatedly caught in banding traps, such as wrens,thrushes,finches,and others.

Weight Variation with Temperature:

Temperature has a profound effect on the weight of birds, and appears to be one of the main environmental factors influencing weight variation. Stoner(1935) made an intensive study on the relationship of temperature to the rate of growth in nestling barn swallows, Hirundo rustica erythrogaster, and came to the conclusion that an increase in temperature resulted in an increase in weight, but with a lag of a day or two. His graph illustrating this interesting phenomenon follows.



Stoner(1945) also conducted a similar experiment on nestling cliff swallows,Petrochelidon pyrrhonota albifrons,and got identical results.Linsdale and Sumner(1934) studied the influence of temperature on weight changes with four golden-crowned sparrows,Zonotrichia coronata,in captivity,and weighed each several times a day for almost two months.They found that "..all four birds increased on the same days and decreased on the same days..".These simultaneous changes in one direction occured too often to be the result of mere chance,for it seemed that some one external factor seemed to have influenced the weight of these birds much more markedly than any others.Weather reports and temperature readings were consulted and the interesting fact was found that every well marked drop in weight was coincident within a day or two after a day of especially high temperature,and conversely all four birds tended to gain weight during cool or cold weather.This gain in body weight during cool or cold weather may not be a direct influence of temperature from a physiologic standpoint, but rather an indirect effect through increased feeding.Many observers have noted that birds feed more on cold days than they do on warm days,thus most birds gain in weight during the winter months with few exceptions.Weaver(1937) for example,found that about twice as many sparrows of several species are caught in banding traps,where they had come for food,on days with the air temperature averaging between seventy and seventy five degrees Fahrenheit,than on days with

the air temperature averaging between eighty and eighty five degrees Fahrenheit.Long(1936) of the University of Michigan showed the same relation between feeding and air temperature in his study on game birds.In the winter of 1935-36,during a period of seventy three consecutive days with the temperature close to or below freezing,fourteen adult bob-whites,Colinus virginianus,consumed an average of 1.72 grams of food per hour per bird,or 17.2 grams for the ten hour day,and six birds of the same species,held as controls at a temperature of seventy two degrees Fahrenheit,consumed only an average 1.29 grams of food per hour per bird,or 12.9 grams for the ten hour day.

Other observers have conducted similar experiments or have observed similar conditions,and have noted the same to be true,namely that birds eat more in cool or cold weather and hence gain in weight.The following two charts,taken from Baldwin and Kendeigh(1938),illustrate the statistical correlation between body weight and air temperature.The first chart shows this correlation in an adult male song sparrow,Melospiza melodia,and the second in an adult male tree sparrow,Spizella arborea.Note that in each case body weight increases with a decrease in air temperature.

Adult Male Song Sparrow:

Average air temperature -Fahrenheit	Weight of bird
33	21.7 grams
40	21.6 grams
42	21.3 grams
49	21.1 grams
53	21.1 grams
58	20.8 grams
63	20.4 grams
68	20.4 grams
73	20.1 grams
78	20.0 grams

Adult Male Tree Sparrow:

17	22.5 grams
24	20.9 grams
29	20.7 grams
33	20.2 grams
39	19.9 grams
43	19.4 grams
47	19.2 grams
52	18.8 grams
57	18.2 grams
62	18.2 grams

Kendeigh(1934) showed that the relation between body weight and air temperature is of considerable interest in the physiological ecology of birds.His experiments showed that heavier birds have greater resistance to low temperature than do lighter birds over periods when food is difficult to obtain, since the extra weight is mostly fat,this fat being used to maintain a higher rate of metabolism at lower temperatures. At higher temperatures the reverse is true.Lighter birds generally have a greater resistence to heat,since the proportion of their body surface area,both external and internal,to body mass is greater,and thus surplus body heat may be dissipated more rapidly.If the bird's weight is really capable of only a limited amount of increase or decrease as a response to temperature,this factor may be of significance in affecting the bird's temperature tolerance and consequently also its distribution,migration,and relative abundance or scarcity in an area.For example if the temperature becomes very low,going beyond the limit to which the bird is able to adjust,the bird's weight may drop to such an extent that it is forced to migrate in search of not only more food,but also for a more suitable environment,with regard to air temperature.

What effect temperature and body weight really have on the migration and distribution of birds is still imperfectly known,but the study of temperature as a possible cause of migration,plus its correlation with body weight,may lead to

some startling discoveries when more information on the subject is available through greater experimentation and research.At least it has been proved that temperature does cause weight variations,often to a marked degree,whereas up to fairly recently in ornithological investigation this factor was not considered to be of much importance.

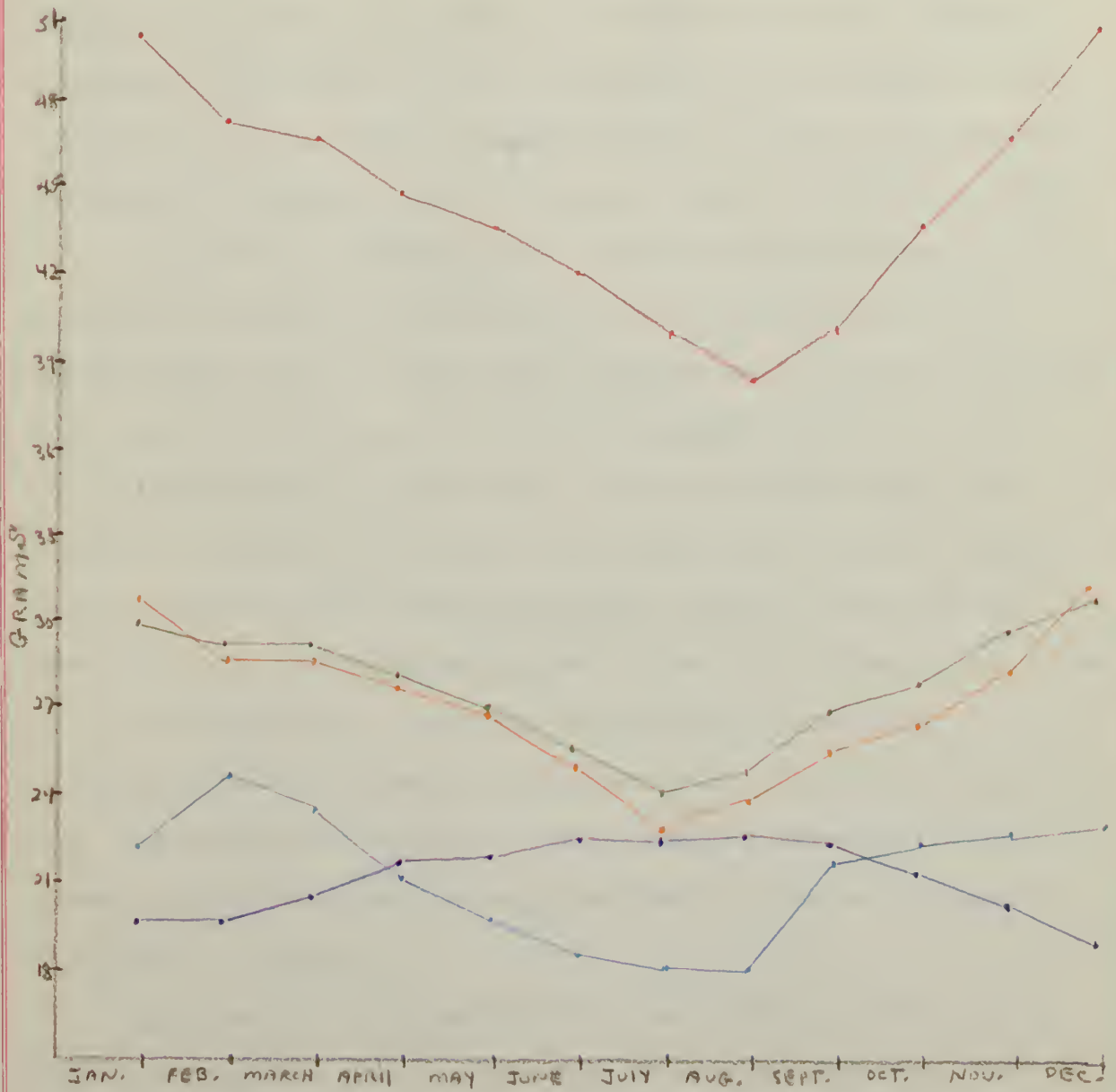
Weight Variation with Time of Year, Migration, and Molt:

These three topics will be covered jointly, since both migration and molt are intimately tied up with the seasons of the year. More data in the literature are available on monthly weight variation in birds during the year than on hourly variation during the day.

That the weight of birds varies during different portions of the spring and fall migration periods has been known for some years in ornithology, and it has been through these careful weight studies taken at banding stations during migration all over the country that the weights of birds have been traced more or less generally for the entire twelve month span. More reliable data are even available for the more or less permanent yearly residents, since they are available at all times for banding and weight study.

Baldwin and Kendeigh(1938) have listed monthly weights throughout the year for some twenty eight species, mainly passerines, but unfortunately certain months are missing in several. However enough species are in a complete enough form to illustrate by graphic means the monthly weight variation in birds. The species selected are those with enough weight records per month to give a good general picture of the yearly trend, and include the English sparrow, Passer domesticus, the song sparrow, Melospiza melodia, the cardinal, Richmondena cardinalis, the downy woodpecker, Dendrocopus pubescens, and the

White-breasted nuthatch, Sitta carolinensis.



As will be seen from this graph, the song sparrow, English sparrow, cardinal, and downy woodpecker all tend to increase in weight during the winter, while the white-breasted nuthatch decreases. This latter bird is definitely an exception to the rule, for as far as data are available, it is the only species in which the lowest weight is found during the winter months.

In general, the weights of landbirds increase month by month until around mid-winter, then decrease again in the spring. There is, it is true, some unevenness in weight variation from month to month in the case of certain species, but the real significance of this must remain uncertain until more extensive data are available. For example, the monthly weight fluctuations of the cowbird, Molothrus ater, as recorded by Nice (1939), in the late spring and summer are opposite to those of other species and would be of special interest in connection with its parasitic reproductive habits, were it not that the records of adults of this species are rather low. Juvenal cowbirds from the data available decrease in weight from June to August.

The possible explanation of these monthly variations in weight throughout the year is one of extreme interest. The uniformity of the change from winter to summer and then back again to winter in so many species seems to imply some constant influencing factor that itself varies in a similar manner. The factor of food amount is of little or no

importance,as seen earlier.The possibility of the effect of less sunshine during the winter has been suggested as a possible factor,but when the average number of hours of sunshine is plotted against the weight curve,no correlation whatsoever is evident,as proved by Stewart(I937).There is a possible correlation existing between monthly variations in relative humidity and weight,but as Kendeigh(I934) pointed out,such a correlation would only be important if there were reason to believe that differences in humidity affected body weight to any appreciable extent,as by influencing the loss of water from the body.The experimental evidence for this is small,and temperature seems to effect the water loss from the body to a much more striking degree than does humidity. Temperature seems to be the main factor in the monthly variation in weight,and as pointed out in the preceding section,the lower the temperature the greater the weight of the bird as a rule.Baumgartner(I938) exemplifies this by her observations on the tree sparrow,Spizella arborea,all the year round in the vicinity of Ithaca,New York,and Churchill, Manitoba.Upon dissecting winter tree sparrows she found that the entire body is not padded after the fashion of ducks and shore birds,but that the fat is found in well defined patches corresponding to the feather tracts,or pterylae,encircling the neck and upper breast,and especially on the lower belly and anal region.This fat was scraped from several specimens and was found to average around I.5 grams,or approximately

7.7 per cent of the total body weight.If this same thing exists in the other passerines and non-passerine land birds,it would undoubtedly explain the winter increase in weight.

The factor of molt enters into the picture of monthly weight variation to some extent,but on reviewing the literature there were found to be two conflicting points of view.One school claims that birds are at their lowest weight of the year during the period of molt,and the other school of thought claims that the renewal of feathers in August and September is not correlated with a decrease in weight,but rather that there is an increase in weight at this time.After the late summer and early fall molt,the bird has the heaviest coat of feathers of the entire year to prepare for the coming winter with its low temperatures,so this extra heavy coat of feathers may act to keep the bird at a higher body temperature by means of insulation,and thus better enable it to survive the severe environmental conditions.The relation of molt to body weight is very poorly understood,and much work must be done in the subject before any concrete statements can be made.From a purely deductive point of view,however,it hardly seems possible that during the exhaustive periods of molt, when the bird is quiet,solitary,and not at all actively feeding,that there could be a gain in weight,but only further study can fully clarify this interesting point.

In birds that migrate long distances during the fall and spring,the variation of their bodily weight during these

periods is of extreme interest.Migration is undoubtedly a tiring process and the mortality rate is often high.More birds go south in the fall than come north the following spring because of the fact that the young or immatures of the previous breeding season accompany the adult birds in the fall,while due to a fairly steady mortality rate,fewer birds return north the following spring.In view of the supposition that birds stop on their migratory journey at various times to rest and regain the energy and weight which they have spent,the following case of a white-throated sparrow, Zonotrichia albicollis,taken from Stewart(I937),seems paradoxical.

Date	Hour	Weight
April 28,I93I	2:00 P.M.	29.00 grams
April 29,I93I	I:00 P.M.	25.50 grams
April 30,I93I	8:00 A.M.	23.50 grams
April 30,I93I	I2:00 noon	24.25 grams
April 30,I93I	8:30 P.M.	23.00 grams

As the above table shows,this individual steadily declined in weight during a stop-over period of three days, until a total of six grams in weight was lost.Stewart(I937) remarked that this bird seemed to be in good health,but little confidence can be attached to the record until corroborative or disqualifying data are available.

Since weight is added after the breeding season is over, as will be further discussed in a later section, it would seem that energy is being stored to prepare for the migration southward, and numerous observers have noted this increase in weight for many migratory species. Whether this weight increase is due to freedom from the cares of raising the young, or whether it is an actual preparation on the part of the bird for migration is not known, however. In the study of the relation of time of migration and body weight, numerous observers have noted that the earliest individuals of a migratory species to depart for the south are lighter than those departing later, so the influence of body weight may possibly be a factor in migration. It may be that individuals vary in their ability to add weight in the form of protective fat, and are thus forced to leave an area because of this factor, while those individuals that can add sufficient fat migrate later when the temperatures are lower. This factor may not only apply to individuals, but also to species, subspecies, and races.

The exact times at which the minimum and maximum weights are attained during the year may vary not only with sex and species, but also to a certain extent with individuals, as mentioned above, and presumably may also be influenced by environmental conditions, locality, and breeding habits. A great variety of reasons are given to explain these monthly changes in bird weight, although there is actually little detailed analysis or experimental verification, and it becomes

increasingly evident that a vast amount of work on the subject must be done before the problem is clarified and fully understood.What work has been done on the subject to date indicates that many perplexing problems may be solved when sufficient data are accumulated.

Weight Variation with Disease and Parasitism:

perhaps no other factor is so influential in imposing variation in bird weights as is that of disease and parasitism. The bob-white, Colinus virginianus, offers a striking example. Stewart(1937) weighed sixty five birds of this species in Ohio during the winter of 1931-32, and found over 77 per cent of the birds to be parasitised. He also noted a weight range of over 100 grams among these fully adult specimens, and in nearly every case the light birds were found to be the most heavily parasitised. The possibility of the light birds being immatures is precluded, since the weights were recorded in the month of February, during which last season's young would have been fully grown. If all weights of heavily parasitised birds could be definitely segregated, they might properly be omitted from the averages of general bird weight, but this is next to impossible, for in order to reach such a conclusion the birds would have to be killed and carefully examined both externally and internally. Without a doubt all birds are parasitised to some extent, especially by bird lice, and many also by round worms, hippoboscid flies, and others, but some are evidently parasitised to a greater extent than others, which undoubtedly lowers the bird's vitality and resistance to infection and disease, and greatly lowers its weight. Once the weight of a bird reaches a certain low level, in the gallinaceous birds at least, the bird reaches a semi-starved condition, after which the weight drops rapidly and often results in death.

Errington(I936) conducted a study of bob-whites,Colinus virginianus,and ring-necked pheasants,Phasianus colchicus torquatus,in Iowa during the winters of I930 through I933,and came to the following conclusions:

(I).Bob-whites,which do not have a pronounced sexual dimorphism,lose weight from hunger at rates which are not appreciably influenced by sex;ring-necked pheasants,which do have a pronounced sexual dimorphism,lose weight at different rates according to sex,the males dying of starvation at an average of 594.3 grams,or 52.5 per cent of their original body weight,and the females dying at an average of 482 grams, or 55 per cent of their original body weight.

(2).Variations in temperature and environmental factors other than food supply,did not appear to greatly affect the dying weights.

(3).In the case of the ring-necked pheasant,even a comparatively slight advantage of the males over the females at dying weight percentages may conceivably have enough winter survival value,under marginal or emergency conditions,to result in a predominately cock population by spring.

Although Errington's paper dealt almost exclusively with starvation and weight loss in relation to food supply,the factors of both disease and extreme parasitism probably have much the same effects on birds,as Stewart(I937) proved on his studies of the bob-white.

When it comes to birds other than game birds, practically no information is available on the subject, but since small birds are subject to disease and parasitism the same as are game birds, it is undoubtedly an important factor in the study of weight variation. The following chart, taken from Baumgartner (1928), while it is not directly concerned with disease or parasitism, shows the loss of weight in dead specimens which is of importance in order to check the value of second and third day weights on collected specimens, the birds in this case being tree sparrows, Spizella arborea.

Loss of Weight in Dead Specimens:

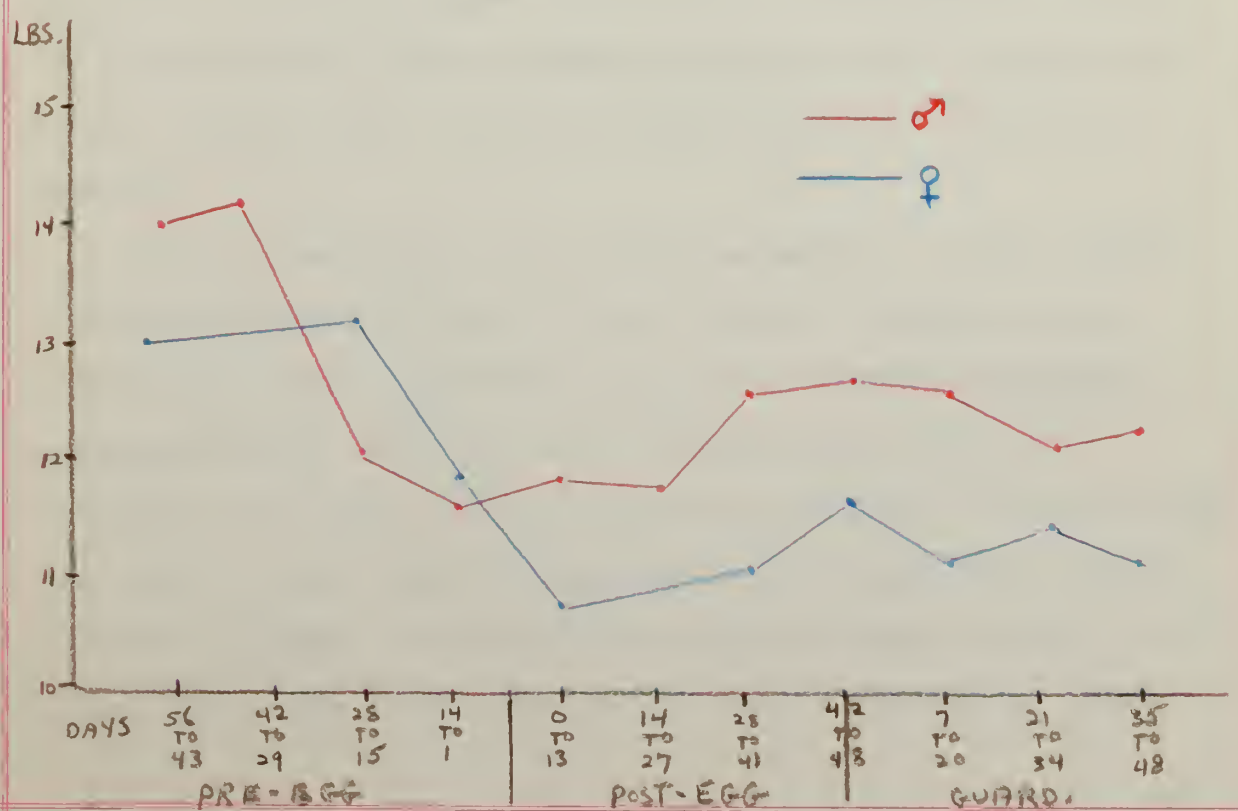
	Loss the first day	Loss in seven days
Two specimens in a cooler	0.4 grams	0.7 grams
	0.3 grams	0.6 grams
One specimen at room temperature	0.5 grams	———

As judged from the meager evidence on hand, disease and parasitism influence weight variation a great deal, and much work remains to be done on the subject in order to ascertain its real importance in the general over-all problem of weight variation in birds.

Weight Variation During the Breeding Season:

The variation in the weight of birds with reference to breeding has been noted by ornithologists for years,but the actual recording of breeding weights is comparatively new. In the majority of birds there is a significant correlation between increase to a maximum body weight and the spring migration.This increase is due to two factors,the deposition of fat,and an enlargement of the gonads.The deposition of fat is probably to not only prepare the bird for its long journey northward,but also for the arduous task of raising a family once it arrives on the breeding ground.Another factor of probable importance is the establishment and protection of a breeding territory by the male birds,which usually arrive first,and which they defend until the arrival of the females. Once the female arrives and mating occurs,the task of nest building,egg laying,incubation,and the raising of the young occurs.As mentioned,the early portion of the breeding season is also marked by an enlargement of the gonads,especially the testes of the male.It is strongly believed by many ornithologists that this hypertrophy commences in the wintering range in the majority of migratory birds,and is one of the underlying factors which causes the birds to return to their northern breeding grounds in the spring.Unfortunately no figures are available to show what percentage the enlarged testes and ovary make up in relation to the total body weight.

As mentioned in the section dealing with egg weights, the female bird gains considerably during the formation of the eggs and up until the time they are laid. Richdale (1947) made an extensive study of the yellow-eyed penguin, Megadyptes antipodes, on the Otogo Peninsula of New Zealand, during which time many valuable observations were made. He found, for example, that the female increases in weight for a time until just before the single egg is laid, and increases also for a time during the post-egg period. The male bird seems to follow this same general plan except that its weight curve is a few weeks ahead of the female's,, and rises a few days before the egg is laid. The following graph, from Richdale's paper, illustrates this phenomenon.



Richdale(1937) believes that increased fat deposition during the early part of the breeding season is an endocrinal response to external environmental factors,which causes a change in body metabolism resulting in the accumulation of extra fat.These bodily changes not only alter the weight but also the behavior pattern of the birds in respect to breeding, which,if it can be proved for birds in general,might provide a clue in the interpretation of avian behavior and psychology.

During the period of incubation many observers have found the weight of the incubating bird to rise.This can possibly be explained by the fact that the incubating bird uses relatively little energy sitting on the eggs,and would thus tend to gain weight,for it still feeds at regular intervals throughout the day.When both sexes share in incubation,both gain in weight; in species where only the female incubates,she gains,but the male's weight falls slightly,probably due to territorial defense.

With the hatching of the eggs,the weight of both adults changes,falling abruptly with the advent of the nestlings. Baumgartner(1938) found that young tree sparrows,Spizella arborea,usually hatch in early July,and that soon after hatching the weight of both parents falls until the fledglings are able to take care of themselves,after which the weight returns to normal as abruptly as it had fallen earlier in the season.From this observation,plus similar records on other

species by various authors,it may be stated that the caring and feeding of the young birds from the time of the hatching of the eggs until the birds can take care of themselves,is one of stress for both parents,and both lose weight during this period.No information is available,but it would be interesting to learn whether there is a similar weight drop in the adults of precocial birds,such as ducks and gallinaceous birds.If a weight loss is not evident in these birds during the raising of their young,it would possibly indicate that the search for food and more or less constant activity throughout the day was responsible;if a weight loss were also evident in these birds it might indicate the influence of some other factor,such as metabolic or endocrine functions.Only further experimentation and research can clarify this problem.

There is a strong possibility that a more careful analysis of the relation of weight variation to the breeding season may explain bird behavior at this time of the year,a subject on which very little is known.

As mentioned previously,the weight of the parent birds rises once the fledglings reach the stage of self-independence. This is due to the fact that without nesting cares,and other drains on their vitality,the adults may now devote a larger share of time to feeding themselves,and are thus able to utilize their energies more completely to adding weight, either for the fall migration in the near future,or to better

tolerate the coming winter conditions,if they do not migrate.

In conclusion,weight during the breeding season fluctuates considerably,probably differing in species if not in individuals,but in general,the male loses weight while defending the breeding territory,the female increases markedly before laying the eggs and during incubation,both parents lose weight while feeding and raising the young,and then both parents increase in weight after the cares of nesting and raising a family are completed.

Weight Variation with Locality and Subspecies:

The study of variation in birds through the analysis of comparative weights has been one method used to designate subspecies,but unfortunately little definite data on the subject are available.Behle(1937) for example,found evidence of a difference in weight between cowbirds,Molothrus ater, in Los Angeles and Pasadena,California,a distance of only a few miles,but gives no evidence as to whether this difference was due to food type or whether it was truly a constant subspecific character.That a bird's weight can change with food type was proved by Baumgartner(1938),when she showed that the width and weight of stomach muscles of red-winged blackbirds,Agelaius phoeniceus,and tree sparrows,Spizella arborea,increased with a change from a granivorous to an insectivorous diet in the summer time.

Various birds have been noted throughout the country by different observers because of their size and weight.For example,Kennard(1932) trapped an exceptionally large red crossbill in Newton Centre,Massachusetts,which weighed 32 grams,possessed a thick bill,very heavy tarsi,and was 155 mm. in length.Upon investigation this bird was found to be a Newfoundland crossbill,Loxia curvirostra pusilla,a distinct subspecies of the red crossbill,Loxia curvirostra curvirostra. Aldrich(1936) shot an exceptionally large woodcock about twenty five miles east of Cleveland,Ohio,which had paler

flesh and much larger bones than the native species, Philohela minor. When the bird was weighed it was found to be 10 ounces, against from 5 to 7 ounces for the native species. This bird was undoubtedly the European woodcock, Scolopax rusticola rusticola, a bird which was never before recorded west of Pennsylvania.

According to Nice(1938), from the evidence on hand there is every reason to believe that the Eastern mourning dove, Zenaidura macroura macroura, is appreciably heavier than the Western mourning dove, Zenaidura macroura marginella, twelve adults of the former averaging 143 grams, and ten adults of the latter averaging only 108 grams. Leopold(1944) compared the weights of the Eastern wild turkey, Meleagris gallopavo, with those of the domestic or barnyard strain, and came to the conclusion that both wild turkey eggs and chicks are smaller than those of the domestic strain, the chicks being about 27 per cent lighter. In each sex and age class he also found the domestic bird to be appreciably heavier than the wild form, but this was probably due mainly to selective breeding. The interesting thing about this study is the fact that the hybrid of the two subspecies is intermediate in weight in the egg, chick, and adult stages. Leopold's table, which follows, brings out this fact with respect to the chicks, and also shows the native bird to possess a larger brain than the domestic strain, with the hybrid again being intermediate. The difference in brain size may possibly explain why the wild turkey is such

a wary and clever bird while the domestic strain in comparison is relatively stupid.

Strain	Number weighed	Chick	Brain
Native	4	55.6 grams	I.866 grams
Hybrid	22	63.2 grams	I.802 grams
Domestic	I4	70.7 grams	I.688 grams

All of the above chicks were of the same age, although how old was not stated.

The problem of subspecies is a very confusing one, especially in the western United States, with no two authorities agreeing as to what constitutes a true species, much less a subspecies. Mayr(I94I), of the American Museum of Natural History, claims that at least ninty four of the seven hundred and fifty five full species of North American birds are considered by some ornithologists to merely be subspecies.

At present most ornithologists recognize some twelve subspecies of the Western horned lark, Otocoris alpestris. Behle(I943) made a very comprehensive study of these races with regard to their average body weights, and his tables show conclusively, that in weight at least, there is a difference. His tables of the twelve subspecies follow, the first being of the males, and the second of the females.

Males:

Subspecies	Number weighed	Average weight
arcticola	27	36.8 grams
merrilli	50	30.3 grams
lamprochroma	78	29.8 grams
utahensis	58	29.5 grams
sierrae	15	31.0 grams
strigata	22	30.0 grams
insularis	17	31.7 grams
rubea	65	29.7 grams
actia	79	28.4 grams
ammophila	43	29.3 grams
leucansiptila	15	30.2 grams
enertera	25	27.7 grams

Females:

arcticola	11	37.6 grams
merrilli	24	28.4 grams
lamprochroma	47	27.4 grams
utahensis	30	27.9 grams
sierrae	8	28.6 grams
strigata	-	-
insularis	9	29.9 grams
rubea	40	27.7 grams
actia	66	26.4 grams
ammophila	13	26.7 grams

leucansiptila	10	28.4 grams
enertera	14	24.7 grams

These twelve subspecies are clearly defined not only in weight,but also in their distribution,although it is believed there is probably more or less of an intermingling between a few subspecies,especially in the Great Plains area,but very little is known about this at the present time.

Bird weights are of extreme importance in the interpretation of geographic variation,and the breaking down of species into subspecies,races,and varieties.As the knowledge of weight and its variation in birds is increased, the possibility exists that many species may be broken up into these various categories,and together with many of the environmental factors already mentioned,several problems existing in the field of ornithology may be solved.

Weight Variation Due to Miscellaneous Factors:

The term miscellaneous is not used in the sense of unimportance,as factors which regulate bird weight,but rather in the sense that little information is known concerning them. When more data are available,they may be of extreme importance.

The first of these so-called miscellaneous factors is indiviuality.Individual variation is a universal rule in biology,applying to all organisms,and one of these variables in birds is weight.Differences occur between the weights of different individuals,but such differences are scarcely greater than may occur in the weight of a single individual at different times,and the individual varies slightly less in weight the more nearly it approaches the average weight of the species.That is why it is so important,when computing the average weight range of a species or set group of individuals, to weigh as many specimens as possible in order to arrive at the true weight range of the species.An example will illustrate the importance of this almost untouched subject.Linsdale and Sumner(1934) weighed four golden-crowned sparrows,Zonotrichia coronata,two males and two females,and found one of the males to be twenty five per cent heavier than one of the females,and twenty eight per cent heavier than the other female.Fortunately four hundred and sixty four birds were weighed before arriving at an average weight range,but if they had based their average on the four above mentioned individuals,the weight range would have been much too high.

Exactly what causes an individual to vary in weight from the general average of the species is probably one or a combination of factors, such as genetic mutation, abnormal functioning of the endocrine glands, disease, food supply, ideal environmental conditions, and other factors. Individual weight variation in birds is practically an untouched field, and one that merits further investigation.

Another factor which causes variations in bird weight, but one in which very little work has been done, is the relationship of the endocrine glands to body weight. Wolfson (1945) has done more work in this field than any other ornithologist in attempting to show the relationship of the endocrine system to weight variation, migration, fat deposition, and the reproductive cycle. Working with Oregon juncos, Junco oreganus, he came to the following conclusions:

(1). The maximum weight of the Oregon junco occurs immediately preceding the spring migration, and is diagnostic of a readiness to migrate.

(2). Fat deposition during the winter can be segregated into four classes; none, little, medium, and heavy.

(3). Resident species studied do not show variations in weight comparable to those shown in migrants.

Wolfson (1945) believes that the physiological response to migrate is manifested by the growth of the gonads, the increase in the secretory activity of the pituitary gland which results

in a heavy deposition of fat, and the increase in body weight to a maximum, but he fails to offer any explanation as to why the gonads hypertrophy and the pituitary gland increases in secretion. In all probability these endocrinal mechanisms are not self-starting, but need some environmental factor or factors to initiate the process into motion.

In another paper by Wolfson(I942) is a table which is of interest since it shows the relation of fat to body weight. The species is the Oregon junco, Junco oreganus.

Date	Number weighed	Sex	Weight	Fat
Jan.4	2	male	-	none
Jan.I6	27	female	I6.0 gms.	medium
Jan.26	7	male	I5.5 gms.	none
Feb.5	5	male	I3.0 gms.	heavy
Feb.5	I5	male	I7.0 gms.	little
Feb.5	37	male	I4.7 gms.	none
Feb.I2	8	female	I5.5 gms.	none
Feb.I2	9	male	I7.5 gms.	little
March I6	62	female	I7.2 gms.	medium
March I6	64	male	I7.2 gms.	medium

Conclusions:

1. The study of the variation in the weight of birds with reference to phases in their life cycles is a relatively new science,being only about twenty five years old at the most.

2. The recording of bird weights has increased with the advent of the live trap and the aluminum band used in studying migration and distribution.

3.The weights of many birds,not only species but also groups, are on the whole very poorly known,and investigation into this phase of the problem offers tremendous possibilities.

4.The passerines and non-passerine land birds have been investigated the most fully,and the vast majority of the work on weight variation has been done with these birds.

5.Weight variation with age seems to be mainly phylogenetic, but egg,nestling,and immature weight variation is also governed by metabolism and other factors.

7.In general,juvenal birds weigh less than the adults during the summer.In many species this difference is erased by fall, but in other species it may persist longer.

8.Weight variation with sex seems to be governed chiefly by phylogenetic and hereditary factors.In the majority of birds the sexes are of nearly equal average weight,but in some species the males are heavier,and in a few species the females

are heavier.

8. Sexual difference in weight may quite possibly be differentiated very early in life, either in the nestling or early immature stages.

9. There is a daily rhythm in the weight of most birds, with the greatest weight occuring in the late afternoon or early evening, and the lowest weight early in the morning.

10. Weight increases most rapidly during the early morning, tapers off during the middle of the day, and increases again during the afternoon. Periods of weight increase correspond with periods of most active feeding.

11. The cooler the weather the greater the food consumption, and the smaller the bird the more in proportion to its size does it eat.

12. The amount of food consumed does not appreciably effect weight, for weight gained during the day is usually all lost at night.

13. There is a yearly rhythm in the weight of most birds, with the greatest weight being reached usually in mid-winter, and the lowest weight usually in mid-summer, and this is inversely correlated with monthly variations in temperature. As a rule spring weight exceeds fall weight. Most species gain weight in winter, but a few do not.

I4. Increased fat deposition seems to either prepare the bird for migration, or to better stand cold weather if it is non-migratory.

I5. Differences in weight-temperature curves and the points at which the limits of variation in weight consistency is reached occurs among many species, and may be correlated with differences in their distribution and migratory status.

I6. Disease and parasitism greatly effect body weight in the species in which this has thus far been studied, particularly the gallinaceous birds.

I7. Weight fluctuates considerably during the breeding season; the male losing weight while defending the breeding territory, the female increasing markedly while laying and incubating the eggs, both birds losing weight while feeding the young, and then both gaining once the young become self-independent.

I8. Weight differences is a means of distinguishing subspecies, not only in their morphological characteristics, but also in their distribution.

I9. Individuality and the relationship of the endocrine glands to weight variation have as yet not been fully enough investigated, but indications are that they may be of extreme importance.

20. The manner and extent of fluctuation in bird weight gives further evidence that birds in their physiological adjustments are highly sensitive to environmental influences, and that this interrelation between function and environment greatly effects their weight and behavior.

Thesis Abstract:

The relationship of the variability in bird weight and the factors involved is yearly growing in ornithological importance,yet up until about twenty five years ago weight variation was accepted as a normal process with little or no significance.As data began to accumulate on the subject, however,it soon became apparent that a careful study of the factors influencing weight variation might clarify some of the unsolved problems existing in the study of birds.As banders throughout the country began recording the weights of their trapped specimens,it became evident that weight was governed by many inter-related factors,which when studied and analysed,seemed to follow a definite pattern throughout the life cycle of the bird.

Since this branch of ornithology is comparatively new, relatively few birds have been weighed in sufficient numbers to arrive at very many definite conclusions.The 'Water and Shore Birds' lack much data,many of the 'Birds of prey' have yet to be studied with regard to weight variation,the land birds,especially the passerines,have had much attention focused on them with regard to this problem,but even they are by no means fully understood.

With regard to the factors which seem to control weight and its variation,some can so far only be explained on a phylogenetic or hereditary basis,such as weight variation with

regard to age. Weight variation is not confined to adult birds alone, but is also exhibited in the egg, nestling, and immature stages, being influenced by body metabolism, nesting habits, and the characteristics of the particular species involved.

The majority of the study of weight variation has been done with adult passerine and non-passerine land birds. If one correlates and analyses data on the subject, it soon becomes evident that certain environmental factors have a definite effect on body weight, an effect which appears to be governed by a more or less stable set of laws. Sexual weight variation seems to be governed by these external factors least of all, heredity appearing to be the major control. The amount of food consumed, individuality, and the number of hours of sunshine have little or no effect on bird weight, but certain other factors are extremely important.

The time of day definitely has its effects on bird weight, for in the majority of birds in which this factor has been studied, the weight falls and rises in correlation with periods of feeding and inactivity, both of which are intimately tied up with the metabolic phenomena of anabolism and katabolism.

Temperature appears to be the main environmental factor influencing weight, and from the evidence on hand, seems to influence phenomena such as fat deposition, fall migration, and distribution. Conclusive studies have proved that in most species a fall in temperature is offset by a gain in weight

and vice versa,and explains why in the majority of birds there is a weight gain during the winter months,the amount of increase depending on the species involved and its distribution.

The time of year,migration,and molt are all important factors,for as a bird's weight may be graphed to follow a set plan during a twenty four hour period,so it may be graphed to follow a set plan throughout a twelve month span. Molt is very poorly understood with reference to this problem,there being two conflicting viewpoints as to whether weight rises or falls during the process.Body weight may determine to a great extent when the fall migration takes place,although its true significance is still a bit uncertain.

Disease and parasitism appear to be of the greatest importance in causing weight variation,since practically one hundred per cent of birds are parasitized to some degree. What work has been done with disease indicates that its effect on weight is tremendous,and often results in death.

Weight variation during the breeding season is intimately associated with the phases of territorialism,nest construction, egg laying,incubation,and the feeding and raising of the young.Many observers believe that body weight together with the functioning of the endocrine glands,especially the gonads,may control bird behavior during this time of the year,for weight seems to correlate very closely with the above mentioned breeding activities.

Weight variation with regard to subspecies, individuality, and the relationship of the endocrine system have not been fully enough investigated to draw many definite conclusions, but all three of these factors, especially the relationship of the endocrine system, will probably be of great significance as future research on them is conducted.

The subject of bird weight and its variation is a field offering unlimited opportunities for research, and the cooperation of both amateur and professional bird students is needed to solve the many problems involved. Weights should be taken at every opportunity, even of dead specimens, for it is only through the accumulation of data that these problems can be adequately attacked.

Bibliography:

I. Addicott A.B. I927. Behavior of the Bush-tit in the breeding season. The Condor.40,49-63.

2. Andrews E.A. I926. (Quoted from Myers,I928).

3. Aldrich J.W. I936. General notes. The Auk.53,329-330.

4. Amadon D. and A.R.Philips,I939. General notes. The Auk. 56,I83-I84.

5. Amadon D. I943. Bird weights and egg weights. The Auk. 60,22I-234.

6. Amadon D. I947. An estimated weight of the largest known bird. The Condor.49,I59-I64.

7. Atwood W.H. I940. Introduction to vertebrate zoology. The C.V.Mosby Company,St.Louis.

8. Baldwin S.P. I924.(Taken from Kendeigh,I940).

9. Baldwin S.P. and S.C.Kendeigh,I938. Variations in bird weights. The Auk.55,4I6-467.

I0. Baumgartner A.M. I938. Seasonal variations in the tree sparrow. The Auk.55,603-6I3.

II. Behle W.H. I937. The cowbirds of the Sacramento Valley, California. The Condor.39,227-228.

I2. Behle W.H. I943. Weights of some western subspecies of horned larks. The Auk.60,2I6-22I.

I3. Bellrose F.C. and A.S. Hawkins,I947. Duck weights in Illinois. The Auk.64,422-430.

I4. Bond R.M. I943. Variation in western sparrow hawks. The Condor.45,I68-I85.

I5. Curtis E.L. I938. Recent literature. The Auk.55,I47.

I6. Davis D.E. I940. Social nesting habits of the smooth-billed ani. The Auk.57,I79-2I8.

I7. Davis W.B. I944. Notes on summer birds of Guerrero. The Condor.46,9-I4.

I8. Edson J.M. I930. Recession in weight of nestling birds. The Condor.32,I37-I4I.

I9. Errington P.L. I936. Sex and resistence of bob-whites and ring-necked pheasants to starvation. The Auk.53,78-79.

20. Esten S.R. I93I. Bird weights of 52 species of birds taken from notes of Wm.Von Gorder. The Auk.48,572-574.

2I. Fowle C.D. I946. Notes on the development of the nighthawk. The Auk.63,I59-I62.

22. Friedmann H. I929. The Cowbirds,a Study in the Biology of Social Parasitism.Charles C. Thomas,Publisher.

23. Grinnell J. I933. Further observations upon the bird life of Death Valley. The Condor.36,67-72.

24. Gross A.O. I937. Birds of the Bowdoin-Macmillan Arctic Expedition. The Auk.54,I2-42.

25. Hartmann F.A. I946. Adrenal and thyroid weights in birds. The Auk.63,42-64.

26. Heinroth O. (Quoted from Amadon,I943).

27. Heydweiller A.M. I935. Some bird and egg weights. The Auk.52,203-204.

28. Hoyt J.S.Y. I944. Preliminary notes on the development of nestling pileated woodpeckers. The Auk.6I,376-384.

29. Immler R.H. and F.P. McMurry,I939. Sex ratio and weights of crows wintering in Oklahoma. Wilson Bulletin.5I,244.

30. Johnson R.A. I935. General notes. The Auk.52,309.

3I. Kendeigh S.C. I934. The relation between body weight and temperature in birds. The Auk.5I.

32. Kendeigh S.C. I940. In memorium,Samuel Prentiss Baldwin. The Auk.57,I-I2.

33. Kennard F.H. I932.General notes. The Auk.49,358.

34. Fortright F.W. I942. The Ducks,Geese,and Swans of North America. American Wildlife Institute,Washington,D.C.

35. Leopold A.S. I943. The molts of young wild and domestic turkeys. The Condor.45,I33-I45.

36. Leopold A.S. I944. The nature of heritable wildness in turkeys. The Condor.46,I33-I97.

37. Linsdale J.M. and F.L.Sumner,I934. Variability in weight in the golden-crowned sparrow. The Auk.5I,55I(rev.).

38. Linsdale J.M. and F.L.Sumner,I937. Weights of spotted towhees. The Condor.39,I62-I63.

39. Long I936.(Taken from Errington,I936).

40. Mayr E. I94I.(Taken from Peterson,I94I).

4I. McIlhenny E.A. I937. Life history of the boat-tailed grackle in Louisiana. The Auk.54,274-295.

42. Montagna W. I940. The acadian sharp-tailed sparrows of Popham Beach,Maine. Wilson Bulletin.52,I9I-I97.

43. Montagna W. I943. Weights and plumages of the horned larks of central New York. The Auk.60,2IO-2I5.

44. Musselmann T.E. I936. General notes. The Auk.53,328-329.

45. Myers F.C. I928. Taking body weights of birds. The Auk 45,334-338.

46. Nice M.M. I938. The biological significance of bird weights. Bird Banding.9,I-II.

47. Nice M.M. I939. Observations on the behavior of a young cowbird. Wilson Bulletin.5I,233-239.

48. Nice M.M. I934. Song sparrows and territory. The Condor. 36,49-57.

49. Palmer R.S. I940. Egg weights of some arctic nesting birds. Wilson Bulletin.52,278.

50. Peterson R.T. I94I. A Field Guide to Western Birds. Houghton Mifflin Company,Boston.

5I. Peterson R.T. I947. A Field Guide to the Birds.-second revision.Houghton Mifflin Company,Boston.

52. Pitelka F.A. I940. Breeding behavior of the black-throated green warbler. Wilson Bulletin.52,3-I8.

53. Poole E.L. I938. Weights and wing areas in North American birds. The Auk.55,5II-5I7.

54. Richdale L.E. I947. Seasonal fluctuations in weights of penguins and petrels. Wilson Bulletin.59,I60-I7I.

55. Scott W.E. I938. Data from ninety eastern crows. The Auk.55,673.

56. Stewart P.A. 1937. A preliminary list of bird weights. The Auk.54,324-332.

57. Stoddard H.L. 1931. The Bob-White Quail. Charles Scribner's Sons,New York.

58. Stoner D. 1935. Temperature and growth studies on the barn swallow. The Auk.52,400-407.

59. Stoner D. 1945. Temperature and growth studies on the northern cliff swallow. The Auk.62,207-216.

60. Sumner E.L. 1929. Comparative studies in the growth of young raptores. The Condor.31,85-111.

61. Taber W.B. 1928. A method to determine the weight of food digested daily by birds. The Auk.44,339-341.

62. Van Gorder W.P. 1931. (Taken from Esten,1931).

63. Walkinshaw L.H. 1937. Leconte's sparrow breeding in Michigan and South Dakota. The Auk.54,309-320.

64. Walkinshaw L.H. 1939. The yellow rail in Michigan. The Auk.56,227-237.

65. Walkinshaw L.H. 1940. Summer life of the sora rail. The Auk.57,153-168.

66. Weaver R. I937. Measurements of growth in the eastern chipping sparrow. The Auk.54,I03.

67. Webster J.D. I942. Notes on the growth and plumages of the black oyster catcher. The Condor.44,205-2II.

68. Williams J.F. I940. The sex ratio in nestling red-winged blackbirds. Wilson Bulletin,52,277-277.

69. Wolfson A. I942. Regulation of spring migration in juncos. The Condor.44,237-263.

70. Wolfson A. I945. The role of the pituitary,fat deposition, and body weight in bird migration.The Condor.47,95-I27.

BOSTON UNIVERSITY
1 1719 02549 2010